S. Folsom 1926

University of Maine

IMPERIAL BUREAU OF MYCOLOGY 8 JAN. 1927

Maine Agricultural Experiment Station

ORONO

BULLETIN 333 JULY, 1926

APPLE SPRAYING AND DUSTING EXPERIMENTS IN 1925.

CONTENTS

	PAGE
Summary	145
Introduction	148
Experiments on Ben Davis at Highmoor Farm	
Times of application	149
Materials and methods	150
Times of infection	151
Scab on the leaves	162
Leaf burning and spotting	167
Scab on the fruit	168
Russeting on the fruit	176
Yield of fruit	179
Cumulative effect of fungicidal treatment	180
Comparison of costs of fungicides	180
Experiments and observations not confined to Highmoor Farm	
Time of ascospore maturity	185
Twigs as source of infection in McIntosh	185
Severity of scab	189
Storage experiments	190
Discussion and general conclusions	198
Seasonal adaptation of schedules	199
Substitutes for liquid lime-sulphur	200
Literature cited	203

MAINE
AGRICULTURAL EXPERIMENT STATION
ORONO, MAINE

THE STATION COUNCIL

PRESIDENT HAROLD S. BOARDMAN,	President
DIRECTOR WARNER J. MORSE,	Secretary
FRANK P. WASHBURN, Augusta,	Committee of Board of Trustees
THOMAS E. HOUGHTON, Fort Fairfield,	Committee of Board of Trustees
HARMON G. ALLEN, Sanford,	Committee of Board of Trustees
FRANK P. WASHBURN, Augusta,	Commissioner of Agriculture
EUGENE H. LIBBY, Garland,	State Grange
WILSON H. CONANT, Buckfield,	State Pomological Society
JOHN W. LELAND, Dover-Foxcroft,	State Dairymen's Association
CHARLES L. JONES, Corinna,	Maine Livestock Breeders' Ass'n.
WILLIAM G. HUNTON, Portland,	Maine Seed Improvement Ass'n.

And the Heads and Associates of Station Departments, and the Dean of the College of Agriculture

THE STATION STAFF

ADMINISTRATION	WARNER J. MORSE, Ph.D.,	Director
	CHARLES C. INMAN,	Clerk
	MARY L. NORTON,	Clerk
	MARGARET M. HONEY,	Clerk
AGRICULTURAL ECONOMICS	CHARLES H. MERCHANT, M. S.,	Economist
	BYRON T. SMITH, M. S.,	Associate
	JOHN L. BABSON, Jr., B. S.,	Assistant
BIOLOGY	JOHN W. GOWEN, Ph.D.,	Biologist
	KARL SAX, Sc. D.,	Biologist
	FORREST V. OWEN, Ph.D.,	Associate
	MARJORIE GOOCH, M. S.,	Assistant
	IVA M. BURGESS, M. S.,	Scientific Aid
	MILDRED R. COVELL,	Assistant
	EMMELINE D. WILSON,	Laboratory Assistant
CHEMISTRY	JAMES M. BARTLETT, M. S.,	Chemist
	ELMER R. TOBEY, Ch. E.,	Chemist
	C. HARRY WHITE, Ph. C.,	Assistant
	BERNIE E. PLUMMER, M. S.,	Assistant
ENTOMOLOGY	EDITH M. PATCH, Ph.D.,	Entomologist
	CLARENCE R. PHIPPS, B. S.,	Associate
	JOHN H. HAWKINS, B. S.,	Assistant
	ALICE W. AVERILL,	Laboratory Assistant
PLANT PATHOLOGY	DONALD FOLSOM, Ph.D.,	Pathologist
	REINER BONDE, M. S.,	Assistant
	THEODORE T. AYERS, B. S.,	Assistant
	LOUISE M. BAKER,	Laboratory Assistant
AROOSTOOK FARM	PERLEY H. DOWNING,	Superintendent
HIGHMOOR FARM	IRVILL H. CHENEY, B. S.,	Superintendent

BULLETIN 333

APPLE SPRAYING AND DUSTING EXPERIMENTS IN 1925.[1]

DONALD FOLSOM

SUMMARY

(1) Mature ascospores (winter spores), which cause the first scab infection of the new leaves in the spring, were not mature before May 15 in as great numbers as in 1924. The first natural infection which they caused on the new leaves probably occurred during May 15 to 19, just previous to the pink application. That this is the time is indicated by the results of artificial infections made at different times and by the collection and examination of leaves from trees representing different experimental plots.

(2) Conidiospores (summer spores) evidently began to spread scab from one leaf to another during the last 3 days of May, midway between the pink and calyx applications, outside of the artificially inoculated tree. Further spread was possible during each rainy period. The spread of scab by the conidiospores from the first spots caused by ascospore infection, occurred to a distance of 8 inches to either side, 6 inches upward, and 18 inches downward. Such spread permits a general distribution of the spots on the leaves early, even if only 1 leaf in 100 is infected by an ascospore.

(3) Artificial inoculations with conidiospores showed that the advance in the maturity of the leaves not only makes them less susceptible to infection, but retards the appearance of the scab spots and the production of spores on the spots.

(4) Conidiospores can live from June to the next April or later under certain laboratory conditions.

---

[1]Previous experimental work of this kind is described in the Maine Agricultural Experiment Station Bulletins 189, 198, 212, 223, 240, 252, 249 (summarizing the preceding six), 271, and 325. A recent publication giving practical recommendations is the Maine Agricultural College Extension Bulletin 160, Fruit spraying and dusting in Maine, by A. K. Gardner, February, 1926.

(5) Scab spots appeared early on the leaves of all plots, but the spread of the disease was checked by spraying. The spread on the trees representing the dusted plots was not significantly different from the spread in the control plots.

(6) As compared with the untreated control trees, in the copper-dusted plots (following Sanders' schedule and using his materials) there was more leaf spotting, apparently due to burning. Lime-sulphur caused less leaf burning than in 1924.

(7) In percentage of fruits affected, scab was significantly more abundant in one copper-dusted plot, one plot sprayed 4 times, and two plots dusted with Pomodust 5 times, than in three plots sprayed 5 times and one plot sulphur-dusted 6 times and sprayed once. Scab on the fruit was also comparatively high in the other copper-dusted plot and in the controls, but was not significantly different in calculations based on the individual tree records. Tree variation as to scab on the fruit could not be explained by correlation with differences in the abundance of leaf infection, in the abundance of scab on the fruit in 1924, in the direction faced by the producing branches, in the density of the foliage, in the fruit color, or in the relative location in the orchard.

(8) The most fruit russeting was associated with copper-dusting and the least was found in the controls. With more spraying there was more russeting, with no effect apparent from adding a casein spreader or from substituting dry for liquid lime-sulphur. Also, with more sulphur dusting there was more russeting, but there was less of such injury than from the same number of applications of spray. Variation as to russeting among the trees with any one fungicidal treatment was not correlated with the direction faced by the producing branches, with foliage density, with fruit color, or with the scab percentage.

(9) The total yield of fruit was not appreciably affected by any fungicidal treatment. Some differences in the proportion of the better grades resulted from the differences in scab and russeting. The amount of cull scab, of scab noted in commercial grading, of scab tallied in the usual experimental sorting, and of scab discovered only by detailed examination, are not the same in per cent of the total crop, and the ratio between them varies. Consequently the method of detecting and grading scab must be adapted to the end in view.

(10) As in previous seasons, the amount of scab on the fruit in any plot was determined by the current season's fungicidal schedule rather than by the amount of scab present on the fruit during the preceding season. The various schedules had no cumulative effect on yield or apparent vigor. No apparent residual effect resulted from the 1924 treatments.

(11) The cost per tree of 4 sprayings with liquid lime-sulphur is 41 cents, of 4 sprayings with dry lime-sulphur is 45 cents, of 5 sprayings with dry lime-sulphur is 54 cents, of 4 sulphur dustings is 40 cents, of 6 sulphur dustings is 53 cents, and of 6 copper dustings is 54 cents.

(12) The small proportion of leaves found to contain mature ascospores (winter spores) together with the time required for examination of the leaves, makes it doubtful whether technical advice can be given that will permit a modification of spray schedules to fit the seasonal and local variation in the time and severity of the first scab infection.

(13) One cause of severe scab infection of McIntosh frequently is twig pustules which enable the disease to overwinter with the consequent production of conidiospores (summer spores) early in the season without previous infection by ascospores (winter spores).

(14) Very few scab spots that are apparent at the time of packing the fruit enlarge during storage, but new spots may develop that at packing were not detected or were detected only by minute examination or by the camera. Temperature and humidity influence the rapidity of development of the storage form of scab. The most important cause of difference was the source of the fruit. Much less storage scab developed on fruit from sprayed trees than on fruit from unsprayed trees. The presence of scab on the fruit for some time previous to picking, as shown by large lesions, resulted in more storage scab. Preliminary experiments gave no evidence of spread of the disease through handling the fruit at packing, or through proximity to scabby fruit in the barrel during storage.

(15) It is concluded that the seasonal adaptation of spraying through expert advice is difficult, if even it is possible, in this State. Also, that lime-sulphur still remains a most generally useful material for the control of apple scab.

INTRODUCTION

The previous published Maine experimental work, done almost entirely in a large Ben Davis orchard on Highmoor Farm, has shown among other things (1) that no one schedule is uniformly best for all seasons even in one orchard; (2) that seven years are not necessarily enough to indicate the true value of a fixed spray schedule for controlling scab, even in one orchard, because the resulting conclusions can then be upset by the next three seasons; and (3) that liquid lime-sulphur is not ideal considering scab control, leaf burning, yield, fruit russeting, and general convenience, but yet with the giving of due consideration to all these characteristics, it still seems to be the best material to use on Highmoor Farm Ben Davis apples at least. A review of the published results of experimental work done in other regions has indicated that these conclusions are reasonable. Another conclusion is (4) that any carry-over of scab in a given plot from one season to another is negligible in the orchard referred to, as far as the control of scab by spraying is concerned. That is, apparently the source of primary infection (ascospores from overwintered scabby leaves) is spread generally over the orchard and its ultimate effectiveness in causing disease in a given group of trees depends much more upon the fungicidal treatment given during the current season than upon the amount of scab noted during the preceding season.

At the beginning of the 1925 season, the previous Maine work together with the available results from elsewhere pointed to a lack of sufficient knowledge concerning certain problems on which work might be done satisfactorily at Highmoor Farm.[2] These were: (1) What various natural conditions cause seasonal variation and contribute to the severity of scab, and how far can they and their effects be foretold for the purpose of adapting spray schedules to the needs of the season? (2) What is the relative value of dry lime-sulphur, of dusts, and of liquid lime-sulphur containing a casein spreader, in comparison with liquid lime-

[2]For every application made there, over 200 miles of travel are required; field laboratory facilities are meager; and there is practically no help available except that of common laborers. Hence experiments that require a continuous series of frequent observations during the season can not be attempted there.

sulphur, when including for consideration the russeting effects on the fruits? (3) Is there a cumulative effect from following the same practice (dust, spray, or no treatment) for two or more years on a given group of trees, through the various effects on leaves, scab infection, and yield? (4) Why is the control of scab much more difficult on McIntosh apples than on Ben Davis, as is considered by some observers to be true? (5) During storage, do scab spots enlarge, does scab spread, or does infection appear as the result of inoculation occurring previous to the time of storage?

EXPERIMENTS ON BEN DAVIS AT HIGHMOOR FARM

Times of Application

The delayed dormant application was made on April 27-28 (on apples outside the experiment), the pre-pink on May 12 (spray) or May 13 (dust), the pink on May 19 (where this was the first application of the season) or on May 20 (where a pre-pink had been applied), the calyx on June 10, the 10-day on June 20, the 20-day on June 30 (dust only), and the 4-week on July 7 (spray) or July 9 (dust). These terms refer to ideal stages in the seasonal development of the leaves and flowers of the trees, as follows:

Delayed dormant—when the first leaves protrude ¼ inch from the buds.

Pre-pink—when some buds are pink, but none have yet separated in the cluster.

Pink—when all the flower buds are pink and most are separated. Or (in the event of the omission of the pre-pink) before the flower buds open and after they are swelled so as to show a trace of pink color.

Calyx—when nearly all of the petals have fallen.

10-day, 20-day, and 4-week—at these stated intervals after the calyx application.

These are referred to as ideal stages. In fact, at the time of the pink application it was noted that even on the same side of the same tree there were flower buds in different stages from "all green and still in contact" to "all pink and all separated." Also, some flowers were still opening at the time of the calyx applica-

tion. The pink application could have been made later and the calyx application earlier as far as the blossom stage was concerned. The actual date for the pink was normal for 15 years' record at this farm, and that for the calyx was 6 days later than the normal.

MATERIALS AND METHODS

The spray materials were applied with the 200-gallon Bean gas-power sprayer used in previous years, using two guns and a pressure of from 250 to 300 pounds. The dust materials were applied with a 1922-model Niagara gas-power machine. Two pairs of plots were given 6 dustings with definite amounts of materials. Here the dust for each application on each plot was weighed into a used paper lime-sack and kept in the dust drum until time for use, when it was put into the hopper. It was then applied as uniformly and completely as possible to that plot. Occasionally it did not reach quite far enough but usually an extra trip was needed to use it up. In a third pair of dusted plots a liberal amount of dust was used and the amount used was determined afterward from what was left of the original weighed lot. Dust was applied to both sides of each row of trees, by the writer. Spray was applied by one or another of three fairly efficient men. The conditions for spraying were generally favorable. The same may be said for dusting except that 2 days' postponement was once made because of wind, which even so was not avoided, and the dust was applied to dry foliage twice (pre-pink and 4-weeks) which is not favorable for the copper dust. Dusting was done between 4 and 6 A.M., usually around 5 o'clock. At the time of visits for the purpose of spraying and dusting, the writer noted that 8 out of 17 mornings were free enough from wind for the satisfactory dusting of plots (for which more than a little drift is undesirable) while all of 13 evenings were too windy. Inspection immediately after dusting showed that the leaves of the trees that were examined were well covered, even in the tops of the trees. Immediately after the pink application of spray, a better spray covering was noted in plots that had received both the pre-pink and the pink than in the plots receiving only the pink application. Also, there was more dwarfing and distortion of the older leaves where a pre-pink had been applied. Further data on this

phase of the work are given in Table 1. The arrangement of the plots is given in Chart 1.

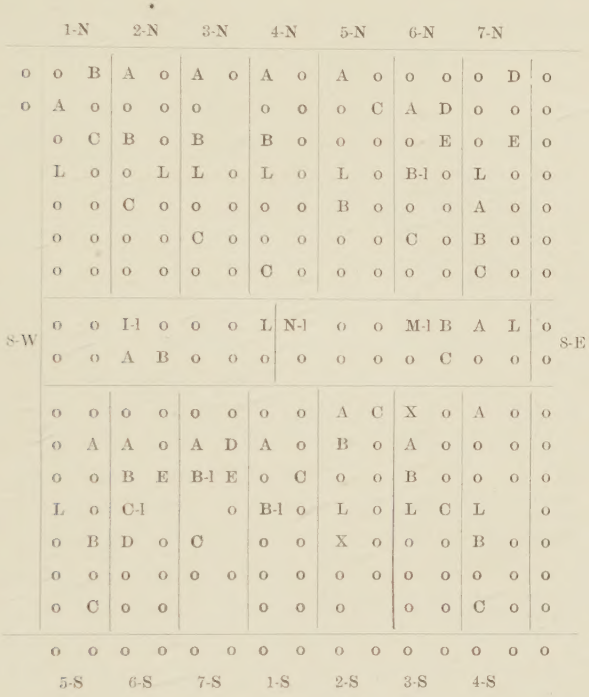

CHART 1. Arrangement of the plots in the 1925 series in the Highmoor Farm Ben Davis orchard. Each letter represents a tree. Capital letters represent count trees (the apples from which were examined.) The numerals refer to the schedules followed (see Table 1).

TIMES OF INFECTION

Dead scabby leaves from the 1924 season were gathered from the ground at various places and were examined for the presence of mature ascospores (winter spores), which when discharged are the cause of the first infection of the new leaves in the spring. The results of this examination are given in Table 2 and will be interpreted later in this bulletin. With reference to the Ben Davis experimental orchard it may be pointed out that no mature ascospores were found in 30 leaves gathered here on

TABLE 1.

Materials used on experimental Ben Davis on Highmoor Farm

Plot No.[1]	Schedule[2]	Total trees	Gallons or pounds applied							Ave. per tree	
			PP	Pk	Ca	10d	20d	4w	Season	Season	Application
1-N, 1-S	PP and Pk, Sanders' 5-3 blue copper arsenic dust; Ca, Sanders' 85-15 sulphur lead arsenate "air-floated" dust; 10d and 20d, Sanders' 5-3 dust; 4w, Sanders' 5-0 blue copper lime dust.	14 14	14	15	21	11	12	13	86	6.1	1.0
2-N, 2-S	PP, Pk, and 4w, 4-50 dry lime-sulphur (4 lbs. to 50 gals. water); Ca and 10d, 4-50 with 1 lb. dry lead arsenate	14 12	110	125	80	105	----	130	550	21.2	4.2
3-N, 3-S	PP, Pk, and 4w, 1.25-50 liquid lime-sulphur (1¼ gals. to 50 gals. water); Ca and 10d, 1.25-50 with 1 lb. dry lead arsenate.	12 14	90	100	70	125	----	150	535	20.6	4.1
4-N, 4-S	Pk and 4w, 1.25-50 liquid lime-sulphur with 0.5 lb. Kayso; Ca and 10d same as for Pk with 1 lb. dry lead arsenate.	14 13	----	100	95	105	----	125	425	15.4	3.9
5-N, 5-S	PP, Pk, Ca, 10d and 4w, Pomodust (90% sulphur and 10% lead arsenate)	14 13	65	60	60	60	----	55	300	11.1	2.2
6-N	Same as for 6-S, with addition, at 10 d, of spray (1.25-50 with 1 lb. dry lead arsenate.)	13	19	20	21	20 70[3]	22 ----	20 ----	122 70[3]	9.4 5.4[3]	1.6 5.4
6-S	PP and Pk, Pomodust (90% sulphur and 10% lead arsenate); Ca and 10d, 85-15 (85% sulphur and 15% lead arsenate); 20d and 4w, Sudodust (sulphur).	12	20	20	21	20	20	20	121	10.1	1.7
7-N	Pk, 1.25-50 liquid lime-sulphur; Ca, same as for Pk with 1 lb. dry lead arsenate.	14	----	60	40	------	----	----	100	7.1	3.6
7-S	Pk and 4w, 1.25-50 liquid lime-sulphur; Ca and 10d, same as for Pk with 1 lb. dry lead arsenate.	10	----	40	30	45	----	60	175	17.5	4.4

[1]See Chart 1 for arrangement of plots. Plots 8-W and 8-E were untreated controls.
[2]The different applications are designated by the abbreviations PP (pre-pink), Pk (pink), Ca (calyx or petal-fall), 10d (10-day), 20d (20-day), and 4w (4-week). For the dates see text, p. 149.
[3]Gallons.

April 28 or in 58 leaves got on May 9, and that they were first found in the 26th leaf examined among 28 gathered on May 12. Evidently the production by scabby leaves of mature ascospores previous to May 15 was low in comparison with that observed in 1924. It is uncertain whether unusual winter conditions such as a light snowfall with exposure of the ground by a February thaw had killed the scab fungus in the dead leaves, or whether spring conditions were unfavorable at least to an early development of the mature ascospores. Whatever the cause, the result that was expected was that the primary scab infection of the young leaves, by ascospores, would be light at least up to the time of the pre-pink application on May 12 and 13. This proved to be the case.

Because of expectation of lightness of natural infection by ascospores, at least early in May, artificial inoculations were made on one of the control trees. Some of the dead scabby leaves gathered on April 28 were placed on moist soil in a damp chamber in a warm room. These furnished mature ascospores for inoculations made May 10 (series "A"). This was just previous to the pre-pink stage. Inoculation was performed by smearing fresh microscopic mounts directly from the glass slides upon the bursting buds. Use was made of a waterproof cardboard carton as a damp chamber (as suggested by F. J. Schneiderhan of the Virginia Agricultural Experiment Station, in correspondence). The result was infection of the pedicels and sepals, a type of infection rarely observed in the 16 years of experimentation in this orchard, and severe infection of the lower surfaces of some of the leaves. Not all the leaves enclosed in the damp chambers were inoculated, but nevertheless of the total leaves enclosed in the chambers the percentage showing scab by June 8 was, for different inoculated shoots, respectively 0, 3, 10, 11, 21, and 32 per cent. Of all the enclosed leaves the percentage was 13 per cent, as against 0.4 per cent (that is, 1 leaf) of 270 leaves on enclosed control shoots and 0 per cent of 100 non-experimental leaves taken at random on the same tree.

These artificial infections showed in the inoculated tree what would have been general in the experimental orchard in the event of heavy natural infection occurring at the same time. They can therefore be compared with the actual observations in the orchard in order to help determine the actual time of natural infections.

TABLE 2.

Examination of scabby leaves from various sources for the presence of mature ascospores

Source	Date[2]	Number of leaves examined: Total	With scab perithecia: Ascospores mature or immature	With scab perithecia: Ascospores mature[1]	Before finding mature ascospores
Orono. Leaves picked from McIntosh and over-wintered on soil under wire netting	March 26[3]	11	0		
	April 8	16	0		
	April 19	15	0		
	April 27	15	0		
	May 1	10	0		
	May 8	19	1	1	11
	May 14	15	0		
	Total	101	1	1	
Hampden. McIntosh leaves gathered from soil	March 22[4]	18	0		
Wiscasset. McIntosh leaves gathered from soil and sent by mail to Orono	April 27	7	0		
	May 4	8	1	1	6
	Total	15	1	1	
Buckfield. Apparently McIntosh. Leaves gathered from soil and sent by mail to Orono	May 7	9	1	0	
Highmoor Farm. Old (early formed) leaves picked from McIntosh and over-wintered on soil under wire netting	April 28	6	0		
	May 9	17	0		
	May 12	10	0		
	May 18	12	1	1	
	Total	45	1	1	
As preceding except young (late formed) leaves	April 28	5	0		
	May 9	11	0		
As preceding except old leaves picked from Ben Davis	April 28	7	0		
	May 9	17	0		
	May 12	9	0		
	May 18	11	0		
Highmoor Farm. Ben Davis leaves gathered from soil after they had fallen naturally.	April 28	12	0		
	May 9	13	0		
	May 12	9	2	1	6
	May 18	10	1	1	5
	Total	44	3	2	
All series at Highmoor Farm summarized	April 28	30	0		
	May 9	58	0		
	May 12	28	2	1	25
	May 18	33	2	2	
	Total	149	4	3	
Selected from April 28 series of preceding, placed on moist soil in warm room	May 9	5	4	4	

[1]Maturity indicated by appearance together with discharge soon after the perithecia were immersed and broken up in water.

[2]Date of gathering given, after which examination was frequently postponed for 1, 2, or 3 days. See text p. 151 and 153, for further discussion regarding the examination.

[3]Examination made April 7.

[4]Examination made March 26 to May 15.

TABLE 3.

Scab and other blemishes on the leaves of experimental Ben Davis on Highmoor Farm

Schedule[1]	Plot No.[2]	Scab					Spots				Burning	
		June 8	June 19	June 29	July 6	August 11	June 8[3]	June 19[3]	July 6[4]	August 11[5]	June 8	June 19
		%	%	%	%	%	%	%	%	%	%	%
Copper dust	1-N	2	3	3	7	-------	40	52	63	-------	9	16
	1-S	1	0	1	3	9	31	27	57	73	4	5
	Ave.	2	2	2	5	9	36	40	60	73	7	11
Dry lime sulphur	2-N	0	0	------	1	-------	3	9	32	-------	1	17
	2-S	0	0	------	0	1	3	11	25	19	6	6
	Ave.	0	0	------	1	1	3	10	29	19	4	12
Spray five times	3-N	0	0	0	0	-------	1	3	25	-------	4	5
	3-S	0	0	0	0	2	4	35	48	9	4	11
	Ave.	0	0	0	0	2	3	19	37	9	4	8
Casein spreader	4-N	0	0	------	0	-------	3	2	23	-------	1	4
	4-S	0	0	------	0	3	2	19	36	7	5	5
	Ave.	0	0	------	0	3	3	11	30	7	3	5
Pomodust five times	5-N	1	0	------	6	5	1	1	15	4	0	0
	5-S	0	1	------	15	29	6	19	20	4	2	3
	Ave.	1	1	------	11	17	4	10	18	4	1	2
Dust and spray[6]	6-N	0	0	1	4	2	15	8	22	10	0	6
Sulphur dust six times	6-S	0	0	4	5	9	23	25	25	24	1	5
Spray twice	7-N	0	0	------	0	1	0	17	12	1	4	5
Spray four times	7-S	1	0	------	0	2	2	26	30	2	1	4
Control	8-E	2	2	3	11	9	5	8	5	6	0	2
		0	3	3	15	11	6	13	16	8	0	2
		1	1	5	5	17	5	4	18	9	0	4
	8-W	0	2	5	9	7	4	14	9	5	0	1
	Ave.	1	2	4[7]	10	11	5	10	12	7	0	2
Inoculated		0	7	12	16	28	11	2	11	2	0	5

[1]See table 1 for full description.
[2]On each date 100 leaves were taken from not more than one tree in each plot, except 3 trees in plot 8-E. See Chart 1 for location of plot and tree (-1 or L).
[3]Spots over 1 mm. (about 1/25 inch) in diameter.
[4]Spots and burned areas over 1 mm. (about 1/25 inch) in diameter.
[5]Spots over 3 mm. (about ⅛ inch) in diameter.
[6]Spray applied once, on June 20.
[7]More spots per leaf (1 to 6) than in other plots (1 only).

Orchard observations were made on 100-leaf collections picked at different times from certain trees. Only one such collection was taken from any tree on a given date. About half of it was picked from twigs within reach of the writer standing on the ground, and half from the upper part of the tree. Twigs for

sampling were selected without deliberate choice except for their being scattered around the tree and all sampled twigs were stripped in order to get leaves of all ages in the collection. The picked leaves were kept in a paper sack and examined individually on both surfaces in the laboratory. This had to be done before wilting was appreciable, because often the only scab spot on the leaf would appear to the unaided eye as a small yellow spot (sometimes only about 1/8 inch in diameter) and in distinguishing such spots due to scab from others not due to scab it was helpful to note, with a hand-lens, the characteristic roughening of the leaf surface which was most apparent while the leaf was still unwilted. Sometimes certainty was possible only by means of microscopic examination. Marked spots of this kind were seen to lose their conspicuousness, such as it was, upon the drying of the leaf. Such small spots do not hurt the leaf much but yet they usually are already furnishing spores for the spread of the disease to other leaves and to the fruits and in this way cause injury.

Because of the variation among trees, work of this kind to be satisfactory requires that at least 500 leaves from each plot, from several trees, be examined at each date. Time was not available for that here. The trees sampled are indicated by "L" or by the suffix "-l" in Chart 1. The results are given in Table 3.

It is seen in Table 3 that scab was apparent on the leaves in sprayed, dusted, and control plots as early as June 8 and that it increased in the controls and dusted plots, and to a smaller extent in the sprayed plots, as the season progressed. This increase is compared with the times of rainfall, of infection, and of applying fungicides, in Table 4.

In interpreting the facts given in Table 4 a general assumption is followed that a period of rainy weather is favorable for a spread of scab provided that living spores and susceptible unprotected leaves or fruits are both present. Some evidence has been reported of a "relation to per cent. of humidity rather than actual rainfall" (28)[3], but that would not disprove the assumption referred to, inasmuch as the humidity is high during a period of rainy weather in this State. Extensive tests were made in Pennsylvania in 1919 to 1923 inclusive. One conclusion is that "a small amount of rain, together with cloudy or drizzly and

[3]Reference is made by number to "Literature cited," p. 203-204.

TABLE 4.

Comparison of rainfall, tree development, and scab development in experimental Ben Davis at Highmoor Farm[3]

Date	Rain[1]	Tree stage	Fungicidal applications	Probable scab infections	Scab lesions on leaves and fruits				
					Inoculated leaves	Inoculated tree[2]	Control plots[5]	Dusted plots[5]	Sprayed plots[5]
1925	Inches				%	%	%	%	%
April 28		Buds bursting	DD						
April 30	0.24								
May 1									
May 4	0.41			Ascospores mature at Wiscasset[4]					
May 5									
May 7				Ascospores nearly mature at Buckfield[4]					
May 8				Ascospores mature at Orono[4]					
May 9		Leaves unfolding		Ascospores mature in H. F. office					
May 10				Inoculation "A" with ascospores performed					
May 11	0.18			Inoculation "B" with conidia of 1924 performed					
May 12		Pink buds rare	PP (spray)						
May 13			PP (dust)						
May 14				Ascospores mature in H. F. orchard					
May 15	0.27			Natural infection by ascospores probable					
May 17	0.16								
May 19	0.05		Pk (where no PP)						
May 20			Pk	Inoculation "C" with ascospores performed					
May 23		Blossoms rare[1]			Inoculation "A" possibly showing lesions[1]				

Comparison of rainfall, tree development, and scab development in experimental Ben Davis at Highmoor Farm[3] —Continued.

Date	Rain[1]	Tree stage	Fungicidal applications	Probable scab infections	Scab lesions on leaves and fruits				
					Inoculated leaves	Inoculated tree[2]	Control plots[3]	Dusted plots[3]	Sprayed plots[3]
1925	Inches				%	%	%	%	%
May 25	0.01			In inoculation "A", first conidial infection probable					
May 26									
May 27	0.08								
May 28		Fourth of blossoms open[1]			Inoculation "A" showing conspicuous lesions[1]				
May 29	0.49			In controls, first natural conidial infection probable					
May 30		Half of blossoms open[1]							
May 31									
June 1		Full bloom[1]							
June 2	0.09								
June 5		Most flowers fell[1]							
June 6		Ready for Ca							
June 7	0.38								
June 8	0.18								
June 9	0.02			Inoculation "D" with new conidiospores performed	13("A") 1("B")	0	1	0-2	0-1
June 10	0.63	Flowers rare Few calyces closing	Ca						
June 13					Second set in "A" appearing[1]				
June 14	0.24								
June 15	0.27								
June 16	0.18								
June 19						7	2	0.2	0
June 20			10d		8("D")				
June 21	2.29			In "A", second natural conidial infection probable					

Comparison of rainfall, tree development, and scab development in experimental Ben Davis at Highmoor Farm[3] —Concluded.

Date	Rain[1]	Tree stage	Fungicidal applications	Probable scab infections	Scab lesions on leaves and fruits				
					Inoculated leaves	Inoculated trees[2]	Control plots[5]	Dusted plots[5]	Sprayed plots[5]
1925	Inches				%	%	%	%	%
June 27-July 6	0.60 (some every day)			Second natural conidial infection probable					
June 29									
June 30		Apples up to inch in diameter	20d (dust)			12	4	2-4	0
July 6					37("D")				
July 7	Shower at noon					16	10	5-11	0-1
July 8		Apples up to 1.5 inch in diameter	4w (spray)						
July 9			4w (dust)		46("D")		1 (fruits)		
August 10									
August 11						20 (fruits)	1 (fruits)		
August 13-14	0.12					28	11	9-17	1-3
August 19	0.03								
September 4	0.32								
September 10	0.03								
September 12	2.12								
September 13	0.58								
September 16-17	1.05								
September 20	0.40								
September 27	0.24								
October 3	1.32								
October 5	0.20								
October 7	0.06								
October 9, 10	1.56								
October 12									
October 17	1.58					34 (fruits)	9 (fruits)	1-14 (fruits)	T-2 (fruits)
October 20						27	5-10	6-17	1-5

[1]From record by Iva A. Merchant, Scientific Aid. The rain gauge was situated about ¼ mile from the orchard.
[2]Excluding the small branches bearing inoculated leaves.
[3]See Tables 1, 2, and 3 for data on percentage of leaves scabby, on maturity of ascospores, and on dates of applications, and on abbreviations.
[4]Introduced for comparison. In McIntosh leaves.
[5]Averages for various schedules recorded here, as given in tables 3 and 8.

foggy weather, when the vegetation is kept wet most of the time, is a much more dangerous condition than a heavy shower, or a washing rain." (24, p. 18.)

As explained above, the result of the inoculations made with ascospores on May 10 ("A") was severe infection. This began to appear about May 23 and was present on 13 per cent of the leaves of the inoculated shoots by June 8, while natural infection had occurred on only about 1 per cent of the leaves taken on June 8 from the control plots (see Table 4) and these consisted of only one spot per leaf. Evidently the first natural infection by ascospores was light and occurred somewhat later than May 10, probably during the rainy period of May 15 to 19, preceding the pink application.

The first spread of the disease by the conidiospores (summer spores) probably occurred in the case of inoculation "A" during the rainy period of May 25-27. It probably did not occur in the controls, which were infected naturally by ascospores, until later, during the rainy period of May 29-31. Supporting this idea, it was found that on June 19 the second set of scab lesions in inoculation "A", which began to appear on June 13, were more advanced than the second set which followed the natural infection. (The second set of lesions, due to conidiospore infection, was distinguished at this time from the first set, due to ascospore infection, by the smaller size, lighter color, fewer spores, greater number per leaf, prevalence on the upper leaf surface rather than the lower, and presence on a younger set of leaves.) Further, the lesions from the inoculation ("D") of June 9 with fresh conidiospores did not appear until at some time between June 20 and June 30. This indicates that the first natural spread by conidiospores in the controls occurred before the rainy period of June 7 to 10.

The infection from ascospores in inoculation "A" was earlier and more severe as compared with the natural infection from ascospores in the control plots. This difference may possibly be the cause of the much greater percentage of infection on the leaves and fruits of the inoculation tree outside of the inoculated branches, at any later date, although a conclusion based on only one inoculated tree is not reliable because of tree variation. (See Table 3, plot 5-S, August 11, where a dusted tree gave a sample with 29 per cent of the leaves scabby.)

After the beginning of spread of scab by the conidiospores, they were of course continually present to spread the disease more during each period of favorable (rainy) weather. Regarding the distance of spread at each time, it was noted that on June 20 the first wave of spread from some of the inoculated branches ("A") extended 8 inches to either side, 6 inches upward, and 18 inches downward. Thus, even with only 1 leaf in every 100 infected naturally by one ascospore, the resulting lesion containing hundreds or thousands of summer spores is within easy reach of the other 99 leaves, so that the increase to an average of 10 per cent leaf infection by July 6 is not surprising, as far as the distance factor is concerned. According to work done in Wisconsin by Frey and Keitt, "it appears, therefore, that the important agency for dissemination of these conidia [summer spores] is meteoric water moving under the influence of wind and gravitation." (9, p. 537.)

TABLE 5.

Variation in leaves of Ben Davis shoot following inoculation with conidiospores

Leaf No.[1]	June 20[2]	June 30	July 8
1	No effects apparent	About 60 spots, some necrotic in center, some only yellow, some sporulating	About as on June 30
2	Do	About 100 spots, a few necrotic in center, a few only yellow, some sporulating	About as on June 30
3	Do	About 40 spots, all yellow, no spores	Some sporulation
4	Do	Do	Do
5	Do	No effects apparent	About 10 yellow spots on stem-end third of leaf, some sporulation
6	Do	Do	No effects apparent
7	Do	Do	Do
8	Do	Do	Do
9	Do	Do	Do

[1]In order of increasing age—from the tip of the shoot downward.
[2]Inoculation performed on June 9 (see Table 4, "D").

The smallness of the percentage of scabby leaves found by July 6, and the absence of much increase between July 6 and August 11 at least in the control plots, is probably due in part to the lateness and lightness of the first natural ascospore infection.

Following that, it is also partly due to a decrease in the susceptibility of the leaves as they mature. Inoculation "C", performed with ascospores on May 20, gave no apparent results, probably because of the leaves of the inoculated flower-bud twigs having become older. The decrease of susceptibility of leaves by age is however illustrated better by the results of inoculation "D" performed on June 9. Here a conidiospore suspension was sprayed with an atomizer on the youngest leaves of growing, non-flowering shoots when the leaves were wet from a 15-hour drizzle, and the inoculated shoots were enclosed inside the cartons for over 24 hours. By June 30 one inoculated shoot, as an example, showed variation between leaves as given in Table 5. Not only were the effects less severe below the 2 youngest leaves, but also the full effects were later in appearance. The same thing was reported in 1925 as the result of inoculations made in Wisconsin (9, p. 538-539.)

It may be pointed out here that the conidiospores may live for several months under certain conditions at least. In June, 1924, scabby Ben Davis leaves were collected, dried, and kept in the general laboratory in paper envelopes until on April 2, 1925. Then summer spores from these leaves were tested in distilled water as to germination. At least 400 spores were counted among those mounted from each of seven leaves and the percentage of germination respectively was 0, 0, 1, 2, 4, 9, and 17 per cent. On May 11, summer spores from the tested leaves were used to inoculate bursting buds (series "B") as had been done with ascospores on May 10 in series "A." On June 8, 3 inoculated shoots had scab on 3, 5, and 11 per cent of the leaves, respectively, while 8 others had none. The infection here was not so marked as with ascospores, the viability of the material being low, but the percentage of infection was greater than in the controls in the same tree. These results may of course not apply to conidiospores exposed to sun and drying wind, but they show that such spores are not necessarily short-lived.

FUNGICIDES IN RELATION TO SCAB ON THE LEAVES

It has been shown in the preceding section of this bulletin that in the general controls the first natural scab infection by ascospores (winter spores) probably began about May 15, that

the conidiospores (summer spores) probably began to spread the disease further about May 29, and that henceforth spread was continuous with recurrent periods of favorable weather, except as maturity made the leaves resistant. It was also stated that scab was also apparent on the sprayed and dusted plots early, and that it increased less on the sprayed plots, but that the amount of leaf sampling was too limited to draw definite distinctions between one sprayed plot and another or one dusted plot and another on the basis of the scab percentages on the leaves. However, it should be pointed out that the average or mean percentage in the sprayed samples was significantly different from that in the controls on both July 6 and August 11. This was not true for the dusted samples. (See Table 6). In brief, spray protected the leaves from scab sufficiently to overcome the effects of tree variation, while dust did not.

TABLE 6.

Comparison of percentages of scabby leaves in Table 3, giving difference between means and probable error of difference,[1] *also ratio between difference and its probable error.*

Means compared		Difference between means and P.E. of difference	Ratio between difference and P.E.
Scab July 6, 5 control trees—11.2±1.21%	Scab July 6, 7 sprayed plots[2]—0.14±0.09%	11.06±1.21[4]	9.1:1
Do	Scab July 6, 5 dusted plots[3]—7.2±1.24%	4.0±1.73[4]	2.3:1
Scab August 11, 5 control trees—14.4±2.29%	Scab August 11, 4 sprayed plots[2]—2.0±0.24%	12.4±2.30	5.4:1
Do	Scab August 11, 4 dusted plots[3]—10.4±4.11%	4.0±4.7	1:1.2

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.
[2]Plots 6-N and 7-N omitted, being sprayed only once or twice.
[3]Plot 6-N omitted, being sprayed in addition.
[4]Fewer scab spots to a leaf in the sprayed plots (1) than in the dusted (1 to 30±) or control (1 to 25±) plots.

Not only was the percentage of scabby leaves less in sprayed trees. Also, the average number of scab spots on each infected leaf was greater for the controls than for the other plots on June

29, and was greater for the controls and dusted plots than for the sprayed plots on July 6. This emphasizes the differences in percentage already described.

As was brought out in the section of this bulletin describing methods and materials, it was considered that a good coating of dust was applied each time. This idea was confirmed, as far as was possible, by ocular examinations made in different parts of the trees. Five or six applications of dust were made in each dusted plot, but only four or five sprayings were put on in each sprayed plot. The Niagara Company and G. E. Sanders, both well-known advocates of dusting, were asked respectively by the writer for advice regarding the materials and methods to be used on two pairs of plots (excluding the pair receiving Pomodust throughout the season.) The Niagara Company (letter of April 2, 1925) explained that weekly applications from one side of the tree were preferable to fortnightly applications from both sides, pointing out that the weekly applications would keep the new growth covered better. Very probably they would also compensate for the washing off of the dust. Such frequent applications could not be made by the writer (see footnote[2]). A heavy shower occurred on June 10, the date of the calyx application, after making that application, and a heavy rain soon followed the 10-day application made on June 20. (See Table 4.) Washing off of the dust by these downpours may explain the increase between June 19 and July 6 of scab apparent on the leaves of the dusted plots in comparison with the scab on the leaves of the sprayed plots.

In Massachusetts on June 9, 1924, after the calyx application, "there was at this time less scab infection on the leaves of sprayed trees than on the leaves of dusted trees, due probably to the more rapid removal of the dust by the frequent rains in May" (5, [p. 3]).

In New York as the result of the development of a new method of determination of the amount of sulphur on foliage, it was found that "during the first few days after an application, the loss of sulfur from the foliage was often rather rapid particularly when dust was used" (7, p. 353). In one test "the sprayed trees received per tree four gallons of 1 to 40 liquid lime sulfur, and the dusted trees received one and one-half pounds of a 90-10 sulfur lead dust." This is about the same as was given to the

trees at Highmoor Farm so that the results are of special interest here. They show that from the second day after treatment until 10 days after treatment, there was nearly 3 inches of rainfall. During this time the amount of sulphur on the sprayed leaves remained the same while over two-thirds of the sulphur was removed in the case of dust. In spite of this, there was still slightly more sulphur left on in the case of dust than in the case of spray. Then the question arises as to whether a given amount of sulphur on the leaves is as finely divided and as effective in the form of dust as in the form of sprayed materials. That it is, is concluded in this report on the New York tests, but a degree of control referred to as being satisfactory admits 10 per cent scabby fruits, which is more than the controls had in 1925 in our orchard, indicating a difference in the general conditions. As pointed out, conclusive results on this point will require several years' work, and the most reliable conclusion established probably is that sprayed sulphur is more adhesive than dusted sulphur, at least during heavy rainfall.

The preceding work was continued in New York, the method used was improved, and the following conclusions were reached:

"It was shown that from 89 to 94 per cent of the sulfur applied as dust was lost from the foliage during the first week; while the losses of sulfur derived from lime-sulphur spray without Kayso varied from 45 to 75 per cent, and with added Kayso from 30 to 57 per cent, during the same period.

"There appeared to be a slight beneficial effect of added Kayso in preventing mechanical losses of sulfur derived from lime-sulfur spray during the first week after application, but no conclusive evidence of any protective effect from the Kayso thereafter.

"From the results of these experiments and from the theory of the probable method of fungicidal effects from sulfur, it appears probable that the fungicidal properties of sulfur are increased in proportion to the fineness, or smallness in size of particles, in which the material exists at the time of its initial application or deposition on the foliage." (23, p. 3).

As related previously, on Highmoor Farm the moisture needed on the leaves for satisfactory adherence of copper dusts was lacking at two applications of this kind of material. It is readily apparent that the resident owner of a commercial orchard, who is not making an experimental comparison between dust and spray both applied at certain times, can make dust applications more frequently and sometimes more timely than was done by the writer in 1925.

On July 6 when examining the leaves for scab, it was noted what percentage of the samples from sprayed plots were apparently not well covered by spray materials. The percentage of evidently well covered leaves varied from 5 to 88 per cent for 8 different trees, being below 80 per cent in 4 instances. This indicates that the spraying was not as thorough as desired, or else that the covering was not readily observed.

TABLE 7.

Comparison between plots as to development of buds and fruits, in experimental Ben Davis at Highmoor Farm

Schedule[1]	Plot No.[2]	Flower buds					Fruit yield				
		April 28[3]	May 9[3]	May 12[3]	May 12[5]	May 20[6]	August 10			October 12[9]	Fruit size October 12[10]
							High[7]	Low	Total[8]		
							Trees	Trees	Bbls.	Bbls.	
Copper dust	1-N	3	3	3	5	4	5	9	7	0.8	16.0
	1-S	2	3	3	5	2	8	6	8	0.8	16.8
Dry lime sulphur	2-N	------	------	------	5	------	8	6	10	1.8	17.1
	2-S	4	5	5	5	4	10	2	11	1.2	15.2
Spray 5 times	3-N	------	------	------	3	------	5	7	6	1.0	16.5
	3-S	3	3	4	2	2	4	10	5	0.8	15.4
Casein spreader	4-N	3	4	4	3	5	5	9	6	1.2	12.3
	4-S	3	5	5	1	4	6	7	6	0.8	13.5
Pomodust 5 times	5-N	------	------	------	1	------	4	10	4	1.1	14.8
	5-S	2	3	2	5	4	10	3	10	1.0	16.8
Dust and spray[4]	6-N	3	4	4	1	2	5	8	5	1.1	14.8
Sulphur dust 6 times	6-S	2	3	3	3	3	8	4	8	1.1	18.8
Spray 2 times	7-N	3	4	4	1	4	3	11	5	1.1	13.8
Spray 4 times	7-S	2	4	4	1	2	4	6	5	1.0	18.4
Control	8-E	------	------	------	------	------	9	4	10	1.3	16.7
	8-W	------	------	------	------	------	10	3	11	0.9	15.4

[1]See Table 1 for full description.
[2]See Chart 1 for location of plot and tree (-I or L).
[3]One labelled bud in each plot measured and drawn, and graded on scale of 1 to 5 in order of increasing size.
[4]Spray applied once, on June 20.
[5]Inside halves (next aisle through plot) of all trees graded from 1 to 5 in order of increasing heaviness of flower bud production, estimated.
[6]Labelled bud graded on basis of increasing proximity to pink stage.
[7]With the final yield of the half-tree next the aisle of the plot estimated as being about 1 bbl. or more.
[8]Estimated final yield for the inner halves of all trees together.
[9]The mean actual yield of the 3 count half-trees chosen because estimated as having the highest yield in each plot.
[10]Based on the fruit yield of October 12, comparing bulk yield and number of fruits, 10.0 signifying 1000 fruits per barrel and 20.0 signifying 500 fruits per barrel. Mean for the same 3 half-trees as are represented in the preceding column.

General observations on the plots on August 10 disclosed no scab on the unpicked leaves of the sprayed plots and less than 10 per cent on the controls, showing that the individual examination of picked leaves is more effective in disclosing the presence of the disease, especially when the lesions are small and rare.

The lack of uniformity of the various trees, or even of the various parts of the same tree, with respect to the blossom stage at any given time, has been referred to. Very probably such variation has some relation to the variation among trees in the effect of a fungicidal treatment. For example, the buds being less advanced in one tree at the time the pink application is given to the whole orchard or plot may result in greater (or less) burning, or in more rapid growth and attenuation of the protective covering immediately following the application with consequent greater scab infection before the calyx application can be applied. No attempt was made to compare different trees in the same plot, but some comparisons were made between plots. (Table 7.) The buds chosen to represent the different plots varied less from each other than the buds on a single tree.

Fungicides in Relation to Leaf Burning and Spotting

As is shown in Table 3, the leaves in the control plots were spotted, becoming more so as the season progressed. Most of these spots were of the frog-eye type, due to the black-rot fungus. As compared with the controls, the sprayed plots gave a somewhat lower percentage at first, increased to a distinctly larger percentage by July 6, and gave more burning. On many of the sprayed leaves the spots were numerous and small, indicating lime-sulphur injury. The Pomodust plots had about the same amount of leaf spotting and burning as the controls throughout the season. The copper dust plots had much more. On the morning of May 20 dew was heavy but was mostly in small drops rather than in a film over the leaf surface. Immediately after the application of the dusts, it was observed by means of a lens that some drops on the copper dusted leaves were blue and clear as though consisting of a copper sulphate solution instead of a Bordeaux mixture as is promised theoretically. Later in the same morning after the dew had dried, many little brown spots were noted on these leaves, though not on the other plots except on 2-N and 2-S,

where they were less numerous. Some of the copper dust had drifted onto the trees of these plots. Also, plots 6-N and 6-S had received sulphur-arsenate dust containing some of the copper dust which could not be entirely blown out of the dusting machine after finishing the copper-dusted plots, and by June 8 displayed similar spots. Such copper-burn spots were more like the frog-eye spots than the lime-sulphur spots in size, but were different in being free from pycnidia and lobar extensions in addition to being more numerous than in the controls. Their greater number comes not only from the higher percentage of affected leaves but also from there being on the average twice as many per leaf, at least at first.

General observations on the plots on June 20 confirmed the conclusions derived above from Table 3, and in addition showed less spotting and burning from the dry lime-sulphur than from the liquid.

Similar general observations made on August 10 did not disclose any marked difference in foliage abundance between the 16 plots. This is different from 1924 when the spray as applied tended to cause some defoliation. On October 14, during picking, each plot was observed and noted as having foliage that was more or less brown and yellow and thin on some trees, except for marked greenness in the west row of plot 2-N, in plots 5-S and 6-S, and especially in the artificially inoculated tree (I-1 in plot 8-W.)

FUNGICIDES IN RELATION TO SCAB ON THE FRUIT

Ascospore infection of the sepals not only occurred in the first inoculation made ("A", p. 153), but probably was the cause of sepal infection on one fruit about ¾ inch in diameter, found accidentally on July 6 in the upper part of a tree in plot 2-N (sprayed beginning with the pre-pink). This fruit bore over a dozen scab lesions on one side below the sepal infection, this side being distorted by the disease.

On August 10, the examination of several hundred unpicked apples without touching them disclosed an occasional scabby fruit, amounting to less than 1 per cent on any tree (sprayed, dusted, or control) except for the inoculated tree. On the latter about 20 per cent appeared scabby. Either these observations did

not disclose all scabby fruits, or the amount of scab on the fruits increased considerably before picking on October 12 to 14.

At picking time three count half-trees were selected in each plot that had duplicate treatment in another plot, and five in each other plot. These count half-trees were facing the aisle through the plot, taken thus to reduce the effect of proximity of the fruits to the foliage of another plot. Because of the marked effects from winter injury occurring several years previously, which made many trees look deficient in foliage and fruit yield, only the 3 or 5 apparently highest-yielding half-trees were chosen to rep-

TABLE 8.

Results from sorting fruits in 1925

Plot[1]	Schedule[2]	Number of apples							
		Total[10]	Smooth[3]	Scabby		Russeted		B grade	Total culls
				All[4]	Culls[5]	All[6]	Culls[7]		
			%	%	%	%	%	%	%
1-N	Copper dust	1496	18	14	1	76	1	80	2
1-S	Ditto	1430	23	2	T[8]	76	5	72	5
2-N	Dry lime-sulphur	3099	67	1	T	32	1	32	2
2-S	Ditto	1887	72	T	T	28	2	26	2
2-S (tree X)	As preceding except no 10-day application	583	82	0	0	18	T	18	T
3-N	Spray 5 times	1789	69	T	0	31	2	30	2
3-S	Ditto	1497	70	T	0	30	2	29	2
3-S (tree X)	As preceding except no 4-week application	710	70	T	0	30	2	28	2
4-N	Casein spreader	2225	68	1	T	31	2	29	2
4-S	Ditto	1689	78	2	T	20	T	22	1
5-N	Pomodust 5 times	2326	84	2	1	14	T	15	T
5-S	Ditto	1738	84	4	1	13	T	15	1
6-N	Dust and spray[9]	2897	76	1	T	24	1	24	1
6-S	Sulphur dust 6 times[9]	2691	67	1	T	32	1	31	2
7-N	Spray twice[9]	2793	73	2	T	25	1	26	1
7-S	Spray 4 times[9]	2207	68	1	T	32	2	30	2
8-E 8-W	Control[9]	3103	82	9	1				
	Inoculated[11]	1956	62	34	2	9 4	T T	17 35	1 2

[1]See Chart 1 for location of plots.
[2]See Table 1 for details of schedule.
[3]Suitable for Maine Standard Fancy or A grades.
[4]Scab seen during the regular examination. See text p. 170.
[5]Scab spots aggregating area of dime. See text p. 171.
[6]Net, spot, or solid even russet over fifth or more of the surface, or solid uneven russet over area ¾ inch or more in diameter. See text p. 176.
[7]Solid uneven russet over third or more of the surface. See text p. 176.
[8]"T" (trace) signifies less than ½ of 1 per cent.
[9]Five apparently highest yielding count half-trees.
[10]Unless otherwise stated, consideration is given here only to the fruits from the 3 apparently highest yielding count half-trees.
The total was divided into smooth, scabby, and russeted, or into smooth, B grade, and culls. The double tallying of apples both scabby and russeted, and the inclusion of fractions of percentages, sometimes result in the percentages totaling more or less than 100.
[11]One tree. See text p. 153.

resent the plot. As shown in Table 7, these count half-trees yielded from 0.8 to 1.2 barrels as an average for the plot, except for 1.8 barrels in plot 2-N. The results of sorting the fruits from these highest yielding half-trees are lumped and given in Table 8.

This sorting refers to an examination during which both ends of each apple were observed. As the apple was turned in the hand, most of the cheek of the apple was also seen. Reasonable rapidity of handling the fruit seemed desirable so that the apples were handled at the rate of a barrel of 600 in about 20 minutes, averaging about 2 seconds to an apple.[4] According to State Inspectors, this was a more rigid examination than is common in commercial practice.[5] On the other hand, a critical examination of the fruits tallied as scab-free, devoting about 30 seconds to each apple with favorable conditions of light, using light reflection from the surface of the fruit, and checking up with a lens in any doubtful instance, showed that many of these fruits were in fact scabby. A few of the newly discovered scabby fruits had been overlooked regarding a single spot on a cheek which was obvious when within range of vision, while most had spots about as small as a pinhead or pinprick, or even spots young enough to be in the blister stage with no dark scab spores showing. (See Fig. 19.) Most of one day was spent in examining fruits from the artificially inoculated tree, tallied as clean, and enough scabby apples were found among them to raise the scab percentage from 34 per cent to 45 per cent. Among 100 supposedly clean fruits from plots 2-N and 2-S, in which no tree had tallied more than 2 per cent scab on the fruits, 9 slightly infected apples had been overlooked. It is obvious that, with a great variation between trees and consequent need for the examination of large numbers of apples, it is impracticable to determine the exact scab percentage including all infected areas visible even to careful ocular examination.

---

[4]Over 41,000 fruits were sorted in this way.

[5]In New Hampshire it is reported for a recent experiment that "all fruit with a scab spot irrespective of size was counted as a scabby apple; but in the case of the non-sprayed trees the fruit was so thoroughly and generally infected as to be worthless, while in the case of the sprayed trees 80 per cent of the scabby apples were marketable and were not materially blemished." (4, p. 5).

As stated, the regular method of examination followed was more rigorous than commercial methods. However, the scab seen was considered as throwing the fruit out of the Standard Fancy and A grades. Further, tally was made of scab severe enough to throw the fruit down below the B grade, into the culls. That condition existed when the scab spots were estimated as aggregating an area as large as a dime (a circle about ¾ inch or 18 mm. in diameter.) (See Figs. 16 and 17.)

The lumped results given in Table 8 give the least scab (1 per cent or less) with 5 applications of liquid lime-sulphur, with 5 applications of dry lime-sulphur, with 4 applications of liquid lime-sulphur, or with six applications of sulphur dusts. There is slightly more scab (1 to 2 per cent) with 4 applications of liquid lime-sulphur containing a casein spreader, or with 2 applications of liquid lime-sulphur. There was still more (2 to 4 per cent or more) with pomodust applied 5 times, with copper dust applied 6 times, or in the controls. One tree in plot 2-S received no 10-day application and yet no scab was seen, and a tree in plot 3-S received no 4-week application without having more scab than the trees lumped for the plot.

Scab of cull severity was absent with 5 applications of liquid lime-sulphur, and was present on 1 per cent of the fruits only with copper dust, with 5 applications of pomodust, and in the controls. (See Figs. 16 and 17.)

The effects of the extremely small scab spots, generally overlooked, will be discussed in relation to the storage experiments.

With only 9 per cent of the fruits of the control plots scabby, conditions were such that spraying for scab apparently did not pay for itself this season in this orchard. The normal scab percentage for control plots in 14 years' records on this orchard is 50 per cent, and is 47 per cent for 15 years' records including that of 1925. Very probably the 15 years' scab percentage would have been much higher for the whole orchard if left entirely unsprayed than it has been for the small parts set aside as "controls," because of the much greater amount of old scabby leaves and of ascospore inoculum that would then be present. Hence the full benefit of spraying as a measure for controlling scab would not be shown by the experimental control plots. This requires instead a long-time comparison between a series of sprayed orchards and a series of unsprayed orchards, all similar except for the spraying.

TABLE 9.

Comparison of percentages of scabby apples in experimental Ben Davis, giving differences between means and probable error of difference;[1] also ratio between difference and its probable error

(Plot below compared with plot to right)	1-S	2-N	2-S	3-N	3-S	4-N	4-S	5-N	5-S	6-N	6-S	7-N	7-S	8-E, W
1-N	11.00±4.01	12.54±4.02	13.37±4.01	13.30±4.01	13.37±4.01	12.54±4.02	11.34±4.01	12.00±4.01	10.34±4.04	13.15±4.01	12.47±4.01	11.95±4.03	12.17±4.04	6.24±4.59
Difference:P.E.	(2.7:1)	(3.1:1)	(3.3:1)	(3.3:1)	(3.3:1)	(3.1:1)	(2.8:1)	(3.0:1)	(2.6:1)	(3.3:1)	(3.1:1)	(3.0:1)	(3.0:1)	(1.4:1)
1-S		1.54±.31	2.37±.18	2.30±.18	2.37±.23	1.54±.31	.37±.25	1.00±.25	.66±.52	2.15±.21	1.57±.25	.95±.43	1.17±.56	4.76±2.25
Difference:P.E.		(5.0:1)	(13.2:1)	(12.8:1)	(10.3:1)	(5.0:1)	(1.5:1)	(4.0:1)	(1.3:1)	(10.2:1)	(6.3:1)	(2.2:1)	(2.1:1)	(2.1:1)
2-N			.83±.26	.76±.26	.83±.31	0±.37	1.20±.32	.54±.32	2.20±.55	.61±.29	.07±.32	.59±.48	.37±.59	6.30±2.26
Difference:P.E.			(3.2:1)	(2.9:1)	(2.7:1)		(3.8:1)	(1.7:1)	(4.0:1)	(2.1:1)	(1:4.6)	(1.2:1)	(1:1.6)	(2.8:1)
2-S				.07±.71	0±.17	.83±.26	2.03±.20	1.37±.19	3.03±.49	.22±.14	.90±.20	1.42±.40	1.20±.53	7.13±2.24
Difference:P.E.				(1:10.1)		(3.2:1)	(10.2:1)	(7.2:1)	(6.2:1)	(1.6:1)	(4.5:1)	(3.6:1)	(2.3:1)	(3.2:1)
3-N					.07±.17	.76±.26	1.96±.20	1.30±.19	2.96±.49	.15±.14	.83±.20	1.35±.40	1.13±.53	7.06±2.24
Difference:P.E.					(1:2.4)	(2.9:1)	(9.8:1)	(6.8:1)	(6.0:1)	(1.1:1)	(4.2:1)	(3.4:1)	(2.1:1)	(3.2:1)
3-S						.83±.31	2.03±.25	1.37±.24	3.03±.52	.22±.21	.90±.25	1.42±.43	1.20±.55	7.13±2.25
Difference:P.E.						(2.7:1)	(8.1:1)	(5.7:1)	(5.8:1)	(1.0:1)	(3.6:1)	(3.3:1)	(2.2:1)	(3.2:1)
4-N							1.20±.32	.54±.32	2.20±.55	.61±.29	.07±.32	.59±.48	.37±.59	6.30±2.26
Difference:P.E.							(3.8:1)	(1.7:1)	(4.0:1)	(2.1:1)	(1:4.6)	(1.2:1)	(1:1.6)	(2.8:1)
4-S								.66±.26	1.00±.53	1.81±.23	1.13±.27	.61±.44	.83±.56	5.10±2.25
Difference:P.E.								(2.5:1)	(1.9:1)	(7.9:1)	(4.2:1)	(1.4:1)	(1.5:1)	(2.3:1)
5-N									1.66±.52	1.15±.22	.47±.26	.05±.44	.17±.56	5.76±2.25
Difference:P.E.									(3.2:1)	(5.2:1)	(1.8:1)	(1:8.8)	(1:3.3)	(2.5:1)
5-S										2.81±.51	2.13±.53	1.61±.63	1.83±.72	4.10±2.29
Difference:P.E.										(5.5:1)	(4.0:1)	(2.6:1)	(2.5:1)	(1.8:1)
6-N											.72±.23	1.20±.42	.98±.55	6.91±2.24
Difference:P.E.											(3.1:1)	(2.9:1)	(1.8:1)	(3.1:1)
6-S												.52±.44	.30±.56	6.23±2.25
Difference:P.E.												(1.2:1)	(1.9:1)	(2.8:1)
7-N													.22±.66	5.71±2.28
Difference:P.E.													(1:3.0)	(2.5:1)
7-S														5.93±2.30
Difference:P.E.														(2.6:1)

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

Although there was not much scab even on the controls, there is some evidence from Table 8 that scab is controlled more effectively by 4 or 5 applications of lime-sulphur (dry or liquid) or by 6 applications of sulphur dusts, than by 5 applications of pomodust or by 6 applications of copper dusts. Each tree's fruit was sorted separately and the individual tree percentages are used in calculations summarized in Table 9. Here the effects of tree variation are taken into account, and note can be made of any difference, between two plots, which is significant as shown by the ratio between the difference and its probable error. There are 13 instances of this ratio being over 5.0 to 1, and 12 such instances occur in the 12 comparisons made between plots 1-S, 4-S, 5-N, 5-S, on the one hand, and plots 2-S, 3-N, 3-S, and 6-N on the other hand. That is, one copper-dusted plot, one plot sprayed 4 times, and both plots receiving Pomodust 5 times, were each significantly higher as to scab percentage than each of the other list of plots, of which three were sprayed 5 times and one was both dusted 6 times and sprayed once. Also, the comparison of plots 1-N (copper-dusted) and 8-E and -W (controls) with the second group gives more significant differences than their comparison with any other plots. These various comparisons help to confirm some of the evidence given by the lumped results of Table 8, stated in the first part of this paragraph.[6]

It has been shown that the percentage of scabby leaves was significantly decreased by spray and not by dust (p. 163 and Table 6.) Each tree from which leaf samples had been collected, was also chosen as a count tree for the fruits. The inside half of the tree was picked for this purpose as in the case of the count half-trees selected on the basis of high yield to represent the plot. A comparison of the leaf percentage and fruit percentage is given in Table 10. Here only 4 trees are included that were also selected on the basis of yield, with their results also included in Table 8. The comparison in Table 10 shows that the leaf percentage got up to August 11 did not necessarily indicate the fruit percentage at picking time. For example, tree L of plot 5-S and tree I-1 of plot 8-W were similar as to leaf percentage, but had fruit percentages of 8 and 34 respectively. On the other hand, larger

[6]Fewer treatments with triplicated plots, as suggested by Brittain (2, p. 141) are preferable.

collections of leaves in August might have shown more correlation between leaf and fruit infection as expressed in percentages.

TABLE 10.

Comparison of scab percentage on leaves and on fruits of the same tree, experimental Ben Davis, Highmoor Farm

Plot	Tree[1]	Scab on leaves[2]		Total apples	Scabby apples		
		June 8-July 6	August 11		All[3]	Culls[4]	All, 1924
		%	%		%	%	%
1-N	L	2-7		266	5	0	
1-S	B-1	0-3	9	511	2	0	
2-N	L	0-1		303	1	0	55
2-S	L	0	1	103	2	1	52
3-N	L	0		343	0	0	3
3-S	L	0	2	134	0	0	
4-N	L	0		550	2	1	3
4-S	L	0	3	165	1	0	8
5-N	L	1-6	5	318	1	T[6]	1
5-S	L	0-15	29	387	8	T	
6-N	B-1	0-4	2	958	1	T	7
6-S	C-1	0-5	9	518	1	0	
7-N	L	0	1	222	2	1	1
7-S	B-1	0-1	2	499	T	0	3
8-W	L	0-9	7	322	5	1	
8-E	L	2-11	9	571	9	2	
	M-1	0-15	11	657	6	T	
	N-1	1-5	17	484	9	T	
8-W	I-1[5]	0-16	28	1956	34	2	

[1]For location of trees see Chart 1.
[2]From Table 3.
[3]Scab seen during the regular examination. See text p. 170.
[4]Scab spots aggregating area of dime. See text p. 171.
[5]Inoculated artificially.
[6]"T" (trace) signifies less than ½ of 1 per cent.

It may be seen in Table 10 that there was no correlation between the scab percentage on the fruit of the same count half-tree in the two years 1924 and 1925. The two trees with high fruit percentage in 1924 were unsprayed during that year, but their fruit was practically scab-free this year. This is in agreement with the conclusion from previous work in this orchard regarding carry-over from year to year in a plot. (See Introduction, conclusion (4), p. 148.) This conclusion is further confirmed by the comparison of the fruit percentages for 1924 and 1925, in Table 11.

Tree variation in respect to the percentage of scabby fruits was especially evident among the count half-trees of the controls and the copper dusted plot 1-N, and somewhat evident in other

plots. An attempt was made to find a correlation with the direction of face of the count half-tree, with the density of foliage, with the fruit color, or with the relative location of the tree in the plot or orchard. Foliage density was estimated on a scale of 1 to 5. Fruit color was designated similarly with the commercial grades as a basis. The foliage density was slightly better on the west face, but there is no consistent correlation between either of these factors and scab percentage on the fruit. The best color was developed only with less density of the foliage, as might be expected, and color seems unrelated to scab here. The two N and S series of plots are parallel, each series consisting of 7 ranks of trees. The two series are separated by the control plots, which lie end to end (Chart 1). In both series the average scab percentage for all the count half-trees is greatest in the rank farthest from the control plots.

TABLE 11.

Comparison of plots of 1924 with included plots of 1925[1]

Plot No.[2]	1-N	2-N	3-N	4-N	5-N	6-N	7-N	1-S	2-S	3-S	4-S	5-S	6-S	7-S
Scab % 1924	3	49	3	5	3	2	2	2	31	6	5	5	3	3
Scab % 1925	14	1	T[3]	1	2	1	2	2	T	T	2	4	1	1

[1]From Table 8 of Maine Agr. Exp. Sta. Bul. 325 and Table 8 of this bulletin.
[2]Identical for the two years. Given here in order of arrangement (See Chart 1).
[3]"T" (trace) signifies less than ½ of 1 per cent.

The only count half-trees (of a total of 62) that had over 11 per cent of the fruits scabby, were tree B of plot 1-N and the artificially inoculated tree (I-1 of plot 8-W). These had 28 and 34 per cent respectively. The former high percentage made the plot percentage and its probable error high for the season. An examination of the tree after picking disclosed its being about 5 feet higher than the others in the orchard. This greater height, together with its being at the end of a row, may perhaps have resulted in its being less completely covered with dust at one or more applications. A leaf collection made after fruit picking gave 14 per cent of the leaves as scabby, but the leaves had begun to fall and the scab percentage was lower on certain other trees than it had been earlier in the season, so that this late sampling is not reliable.

It may be pointed out that 5 applications of Pomodust in 1924, with much more scab on the controls than in 1925, gave control of fruit scab about like that got with spray. On the other hand, a similar Pomodust schedule in 1925 ranked with copper dust and the controls in giving scab control that is significantly inferior to that got with 5 applications of spray. This brings out once more the fact that seasonal variation makes several years' tests necessary for reliable conclusions. Possible explanations for the shift in the relative effectiveness of the Pomodust schedule have been given in discussing the results of the leaf sampling (p. 164).

FUNGICIDES IN RELATION TO RUSSETING ON THE FRUIT

On August 10, general observations disclosed some russeting in the control plots but more in the others. The same general type was noted in the control, sprayed, and dusted plots. In addition, in the copper dusted plots there was another kind characterized by many small dark brown spots.

While sorting the fruits for scab percentages, russeting was tallied. Here, as in regard to scab, the inspection was more rigorous than is common in commercial practice. Russeting was not recorded unless it covered a fifth or more of the fruit's surface, when of either the net, spot, or solid even type (Figs. 21, below, 22, and 23, on left), or unless it was of the solid and uneven type (Fig. 23, on right) and covered an area as large as a dime (a circle about ¾ inch or 18 mm. in diameter.) The solid even type has the surface not uneven or warty to the eye though somewhat rough or unpolished to the touch, and may cover a considerable area near the stem of the apple without materially injuring the appearance of the fruit (Fig. 22, below). Russeting was considered to be of cull-producing severity when of the solid uneven type (Fig. 23, on right) covering over a third of the fruit's surface.

The lumped results from the highest yielding trees are given in Table 8, where it is seen that the least russeting (9 per cent) was found in the control plots. There was somewhat more with Pomodust, and most of all with copper dust, with the other treatments falling in between, mostly in a bunch. The same relationship holds for the cull type of russeting considered alone.

TABLE 12.

Comparison of percentages of russeted apples in experimental Ben Davis, giving differences between means and probable error of difference;[1] also ratio between difference and its probable error

(Plot below compared with plot to right)	1-S	2-N	2-S	3-N	3-S	4-N	4-S	5-N	5-S	6-N	6-S	7-N	7-S	8-E, W
1-N	0±3.54	44.00±3.96	48.33±3.47	45.33±3.86	44.66±3.95	46.66±3.82	56.00±3.31	62.33±3.57	63.33±3.73	53.13±3.30	44.73±4.17	50.53±4.62	45.93±3.58	66.93±3.30
Difference:P.E.		(11.1:1)	**(13.9:1)**	**(11.7:1)**	(11.3:1)	(12.2:1)	(16.9:1)	(17.5:1)	(17.0:1)	(16.1:1)	(10.7:1)	(10.9:1)	(12.8:1)	(20.3:1)
1-S		44.00±2.89	48.33±2.18	45.33±2.76	44.66±2.88	46.66±2.70	56.00±2.95	62.33±3.23	63.33±3.40	53.13±2.94	44.73±3.88	50.53±4.36	45.93±3.24	66.93±2.93
Difference:P.E.		(15.2:1)	(22.2:1)	(16.4:1)	(15.5:1)	(17.3:1)	(19.0:1)	(19.3:1)	(18.6:1)	(18.1:1)	(11.5:1)	(11.6:1)	(14.2:1)	(22.8:1)
2-N			4.33±2.81	1.33±3.28	.66±3.38	2.66±3.23	12.00±2.61	18.33±2.93	19.33±3.12	9.13±2.60	.75±3.64	6.53±4.15	1.93±2.94	22.93±2.59
Difference:P.E.			(1.5:1)	(1:2.5)	(1:5.1)	(1:1.2)	(4.6:1)	(6.3:1)	(6.2:1)	**(3.5:1)**	**(1:5.0)**	(1.6:1)	(1:1.3)	(8.9:1)
2-S				3.00±2.67	3.67±2.79	1.67±2.61	7.67±1.79	14.00±2.23	15.00±2.47	4.80±1.77	3.60±3.10	2.20±3.68	2.40±2.24	18.60±1.76
Difference:P.E.				(1.1:1)	(1.3:1)	(1:1.6)	(4.3:1)	(6.3:1)	(6.1:1)	(2.7:1)	(1.2:1)	(1:1.7)	(1.1:1)	(10.6:1)
3-N					.67±3.26	1.33±3.10	11.33±2.46	17.00±2.79	18.00±2.99	7.80±2.44	.60±3.53	5.20±4.05	.60±2.80	21.60±2.44
Difference:P.E.					(1:4.9)	(1:2.3)	(4.9:1)	(6.1:1)	(6.0:1)	(3.2:1)	(1:5.9)	(1.3:1)	(1:4.7)	(8.9:1)
3-S						2.00±3.21	11.34±2.59	17.67±2.91	18.67±3.10	8.47±2.58	.07±3.72	5.87±4.13	1.27±2.92	22.27±2.57
Difference:P.E.						(1:1.6)	(4.4:1)	(6.1:1)	(6.0:1)	(3.3:1)	(1:51.7)	(1.4:1)	(1:2.3)	**(8.7:1)**
4-N							9.34±2.39	15.67±2.74	16.67±2.94	6.47±2.38	1.93±3.48	3.87±4.01	.73±2.75	20.27±2.37
Difference:P.E.							(3.9:1)	**(5.7:1)**	(5.7:1)	(2.7:1)	(1:1.8)	(1:1.0)	(1:3.8)	(8.6:1)
4-S								6.33±1.97	7.33±2.24	2.87±1.44	11.27±2.92	5.47±3.53	10.07±1.99	10.93±1.42
Difference:P.E.								(3.2:1)	(3.3:1)	(2.0:1)	(3.9:1)	(1.6:1)	(5.1:1)	(7.7:1)
5-N									1.00±2.60	9.20±1.96	17.60±3.21	11.80±3.77	16.40±2.39	4.60±1.94
Difference:P.E.									(1:2.6)	(4.7:1)	(5.5:1)	(3.1:1)	(6.9:1)	(2.4:1)
5-S										10.20±2.23	18.60±3.38	12.80±3.92	17.40±2.62	3.60±2.22
Difference:P.E.										(4.6:1)	**(5.5:1)**	(3.3:1)	(6.6:1)	(1.6:1)
6-N											8.40±2.91	2.60±3.52	7.20±1.97	13.80±1.40
Difference:P.E.											(2.9:1)	(1:1.4)	(3.7:1)	(9.9:1)
6-S												5.80±4.34	1.20±3.22	22.20±2.90
Difference:P.E.												(1.3:1)	**(7.7:1)**	
7-N													5.40±3.78	16.40±3.52
Difference:P.E.													(1.4:1)	(4.7:1)
7-S														21.00±1.96
Difference:P.E.														(10.7:1)

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

Using the individual tree percentages as was done for scab, calculations were made which, summarized in Table 12, show that further separation can be made in the group of plots having more russeting than the controls and the Pomodust, and less than the copper dust. Here significance of a difference between means is granted on a ratio of 6.0 or more to 1 between the difference and its probable error. Plot 7-N (sprayed twice) was like the controls (plots 8-E and 8-W) and the Pomodust plots (5-N and 5-S) in being significantly less russeted than the plots sprayed 5 times or copper-dusted. Next comes plot 7-S (sprayed 4 times) with significantly more russeting than the Pomodust plots but less than the plots sprayed 5 times or copper-dusted, together with several plots that are between the Pomodust and the others just mentioned but not significantly different from either (plots 4-N and 4-S, sprayed 4 times using a casein spreader; plot 6-S, sulphur-dusted 6 times; and plot 6-N, sulphur-dusted 6 times and sprayed once.) Next on the scale come the plots sprayed 5 times with either dry or liquid lime-sulphur (2-N, 2-S, 3-N, and 3-S.) These have significantly more russeting than the Pomodust plots and less than the copper-dusted.

In brief, with more spraying there was more russeting, with no effect shown from adding a casein spreader or from substituting dry for liquid lime-sulphur. Also, with more sulphur dusting there was more russeting, with less of such injury however, than from the same number of applications of spray. Copper dusting is in a class entirely by itself, causing much russeting.

Considering the individual tree records, russeting in any plot was not correlated with the direction in which the count half-tree faced, with foliage density, with fruit color, or with the scab percentage, except for russeting being comparatively low for the two trees with the highest scab percentage, one tree being copper-dusted and the other inoculated.

In plot 2-S, the omission of the 10-day application of spray (tree X, table 8) was associated with a decrease in russeting. On the other hand, the addition of a 10-day application of spray in plot 6-N was also associated with a similar decrease in russeting, for a whole plot. The omission of the 4-week application of spray in plot 3-S (tree X) had no such effect.

Fungicides in Relation to Yield of Fruit

As is shown in Table 7, where the yield as estimated on August 10 was only 4 to 6 barrels for a plot, the record for estimated heaviness of flower bud production on May 12 had also been low. On August 10, some fruits in clusters were being starved off of the inoculated control tree. This tree finally gave 4 barrels, a high yield for this orchard.

As described in the discussion of scab on the fruit, the several apparently highest yielding inside half-trees were selected for sorting. With the average yield of half-trees differing for duplicate plots as much as 1.2 to 1.8 barrels (plots 2-N and 2-S) and 0.9 to 1.3 (control plots), the range in yield of the various plots, from 0.8 to 1.8, can not be attributed to the effects of the fungicides used. Further, the fruit size is not larger with lower tree yields, as it was in 1924 when a given fungicide, as applied, caused perceptible fruit drop. It is thought that the use of the spray guns was more skillful this season and that this explains at least most of the interseasonal difference. In a recent report on spray injury to apple, wherein various types are distinguished, the "edge burn" type "appears to be more severe in the paths of the spray gun." (*27*, p. 408). This report also concludes that "the complete change of lime-sulphur to precipitated sulphur and calcium sulphate requires from one-half to two hours. If this process is retarded and if conditions are favorable, the soluble sulphides may burn" (p. 415).

In addition to the total yield of fruit, it is important to know the yield in the best grades. Grading factors were ignored from force of circumstances except for scab and russeting. There was only a trace of insect injury of all kinds. With scab low for most plots, russeting was more important in the reduction from Fancy and A standard grades to B and cull grades. As shown in Table 8, the highest percentage of smooth fruits was got in the Pomodust and control plots. The percentage was about the same for 5 sprayings with dry lime-sulphur as for 5 with the liquid (plots 2-N, 2-S, 3-N, and 3-S.) It was low for copper dusting. The cull percentage was practically negligible for comparative purposes. Hence the B grade depended on the amount of smooth fruit.

With more scab, such as is seen in some years, this result of the most smooth fruits occurring with about the most scab present (Pomodust and control plots) would of course not be expected. As suggested previously, the method of grading makes a difference in the yield of fruits sold under the best grades. Two schedules appearing alike under one system of grading might appear quite different with a change in the severity of inspection.

CUMULATIVE EFFECT OF FUNGICIDAL TREATMENT

It has been shown in a preceding bulletin (18) that in several different years there was no apparent carry-over of scab in a given plot from the preceding season. (See also p. 174 of this bulletin.) However, this conclusion is based on work in which the policy was followed of shifting the check plot each year. The results might be different if a plot is sprayed, left untreated, or dusted for several successive years. Cumulative effects as to scab might be added to or even overshadowed by the effects as to vigor and yield through differences in leaf burning and fruit dropping, such as resulted from spraying in 1924. A cumulative effect could show as a progressively greater difference between plots with different treatments, or could be indicated by a residual effect apparent the first year after putting plots with previous different treatment together under the same treatment, but would not be proved by only a distinct average difference year after year as this might be a direct effect and not a cumulative one. According to this definition a cumulative effect may be tested by comparing plots 3 and 7 (sprayed 1924 and 1925) with plot 2 (untreated 1924, sprayed 1925) and with plot 5 (dusted 1924 and 1925.) The last, plot 5, may be compared with plot 6 (sprayed 1924, dusted 1925.)

These comparisons, as may be expected from the previous comparisons as to scab and yield rates, show no cumulative effects, either progressive or residual. An instance is reported from Great Britain of the effect of fungicides being apparent three years later (10).

COMPARISON OF COSTS OF FUNGICIDES

In a previous bulletin a method was presented for determining the probable cost and net profit of spraying 100 trees four

times, basing figures upon past experience as to control etc. and upon current costs of materials. Following the same method, a computation is made of the cost of spraying each tree with dry lime-sulphur four times (cost 45 cents), with liquid lime-sulphur four times (cost 41 cents), with dry lime-sulphur five times (cost 54 cents), and with liquid lime-sulphur four times with a casein spreader added (cost 42 cents). The details follow.

Dry lime-sulphur four times

Unit considered, 100 trees (70 trees per acre)	
Number of applications, 4 per season.	
Amount applied per tree, 16 gallons per season.	
Total applied to 100 trees, 1,600 gallons.	
Total dry lime-sulphur at 4-50, 128 lbs.	
At 10½ cents a lb. including freight charges	$13.44
Total dry lead arsenate at 1-50, two applications, 16 lbs.	
At 20½ cents a lb. including freight charges	3.28
Team and teamster for 1½ days at $3 for each per day (10-hour day)	9.00
Two laborers for 1½ days at $3 for each per day	9.00
Original cost of 200-gallon sprayer, $500	
1000 trees cared for.	
Interest on sprayer at 5 per cent, $25.00; for 100 trees	2.50
Individual tree sprayings per season, 4,000	
Life of sprayer, 40,000 tree sprayings.	
Depreciation from 400 tree sprayings (1/100 of $500)	5.00
Annual repair of sprayer for 4,000 tree sprayings, $20	
Repair for 400 tree sprayings	2.00
Gasoline and oil per 400 tree sprayings	0.30
Total cost of spraying 100 trees for one season with 4 applications of dry lime-sulphur and 2 of lead arsenate (combined)	44.52

Liquid lime-sulphur four times.

Total liquid lime-sulphur at 1¼-50, 40 gals.	
At 24 cents a gallon including freight charges	9.60
Dry lead arsenate as above	3.28
Team, teamster and laborers as above	18.00
Machinery costs as above	9.80
Total cost of spraying 100 trees for one season with 4 applications of liquid lime-sulphur and 2 of lead arsenate (combined)	40.68

Dry lime-sulphur five times (pre-pink added).

Dry lime-sulphur as above plus 25 per cent	16.80
Dry lead arsenate as above	3.28
Team, teamster, and laborers as above plus 25 per cent	22.50
Interest on sprayer for 100 trees per season	2.50
Depreciation, repair, gasoline, and oil for 500 tree sprayings	9.13
Total cost of spraying 100 trees for one season with 5 applications of liquid lime-sulphur and 2 of lead arsenate (combined)	54.21

Cascin spreader in liquid lime-sulphur.
Liquid lime-sulphur in 4 applications, total as above..... 40.68
Kayso, 8 lbs. at 21 cents a lb. including freight charges..... 1.68
Total 42.36

Although we have had less experience with dusting procedure and machinery than with spraying, a similar attempt is made to determine the probable cost of comparative dusting. In doing this, the materials are listed as containing arsenic at only two applications. Actually arsenical dust was used four times and arsenical spray only twice. Thus the dusting method is given credit for control as good as spray while it is assessed less cost than was actually incurred during the season. Also there is much conjecture as to the rate of dusting, the life of the machine, etc. The work was done with a tractor while the costs are based on work with a team. The amount applied per tree was according to the manufacturer's recommendation received through a representative who had seen the experimental orchard. The Niagara dust schedule cost 53 cents per tree and the Sanders' dust schedule cost practically the same. Four applications of sulphur dust would cost 40 cents per tree. The details follow.

Sanders' dust six times.
Unit considered, 100 trees (70 trees per acre).
Number of applications, 6 per season.
Four applications of 5-0 copper lime dust.
One pound per tree at each application.
400 pounds at 6.25 cents per pound including freight charges....$25.00
One application of 85-15 sulphur-lead arsenate dust
1½ lbs. per tree at each application.
150 lbs. at 8.5 cents per lb. including freight charges..... 12.75
One application of 5-3 blue copper arsenic dust.
One pound per tree at each application.
100 lbs. at 8.5 cents per lb. including freight charges..... 8.50
Rate of dusting, 100 trees per hour, 1,000 per day.
Team and teamster for 6 hours at $3 for each per 10-hour day..... 3.60
Laborer for 6 hours at $3 per 10-hour day..... 1.80
Original cost of duster, $435
4,000 trees cared for.
Interest on duster at 5 per cent, $21.75; for 100 trees..... 0.54
Individual tree dustings per season, 24,000
Life of duster, 240,000 tree dustings.
Depreciation from 600 tree dustings (1/400 of $435)..... 1.00
Annual repair of sprayer for 24,000 tree dustings, $?
Repair for 600 tree dustings.....
Gasoline, oil, and grease for 600 tree dustings..... .35

Total cost of dusting 100 trees for one season with 6 applications of Sanders' materials..... 53.63

Niagara dust six times.
Four applications of Sulfodust
1½ lbs. per tree at each application.
600 lbs. at 3.75 cents a lb. including freight charges..... 22.50
Two applications of 85-15 dust.
1½ lbs. per tree at each application.
300 lbs. at 7.85 cents a lb. including freight charges..... 23.55
Team, teamster, and laborer as for Sanders' dust..... 5.40
Machinery costs as for Sanders' dust..... 1.98
Total cost of dusting 100 trees for one season with 6 applications of Niagara materials..... 53.43

Pomodust five times.
Five applications, 2 lbs. per tree at each application
1000 lbs. at 6.75 cents per lb. including freight charges..... 67.50

Niagara dust four times.
Two applications of Sulfodust
1½ lbs. per tree at each application.
300 lbs. at 3.75 cents a lb. including freight charges..... 11.25
Two applications of 85-15 dust as above..... 23.55
Team, teamster, and laborer for 4 hours at $3 for each for 10-hour day..... 3.60
Interest on duster..... 0.54
Depreciation from 400 tree dustings (1/600 of $500)..... 0.73
Repair, gasoline, oil, and grease for 400 tree dustings..... 0.25
Total cost of dusting 100 trees for one season with 4 applications of Niagara materials..... 39.92

According to these figures dust would cost slightly less than liquid lime-sulphur if only four applications were made.[7] Whether four applications of dust, with arsenic in it twice, would control scab as well as the four applications of liquid lime-sulphur which constitute the standard schedule for Highmoor Farm Ben Davis at present, is not known. Probably it would not, judging from the results of the 1925 tests described in previous pages of this bulletin. Here the best comparison for nearly equivalent scab control would be between 5 applications of dry lime-sulphur (the liquid not being easily bought in small lots in 1926) with a cost

[7]The cost of supplying water and of hauling materials from the freight station and storing them is not included in the accounts that are given in this bulletin.

of 54 cents per tree as against 6 applications of sulphur dust with a cost of 53 cents per tree. Judging from the scab on the leaves, more dust applications might be needed in some seasons to get the best scab control. This might be gained by "split" applications. (See p. 164.)

In Massachusetts "four applications of lime-sulphur solution without spreader may be regarded as the standard treatment." There, "as to whether spraying or dusting is cheaper depends on the facilities for spraying, the distance from the water supply, the size of the spray tank, the size of the trees, and how many applications of dust are considered necessary. Five applications of dust were enough in 1924. This being the case, it was as cheap to protect by dusting as by spraying at Middlesex Fruit Farm. At the other two orchards, with smaller trees and less time spent in going for water, protection proved somewhat cheaper by spraying than by dusting, provided that our cheapest spray material is considered. In most orchards where dry lime-sulfur and spreader is to be used, it is probable that the cost will not be far from that of dusting." (5, [p. 3, 6].)

In Nova Scotia (2, p. 144) an average application of 800 gallons per day resulted in a cost of 1⅞ cents per gallon. This would be 30 cents a tree at the rate of use in the estimate given in this bulletin, at 4 applications a season. Also, an average application of 2500 pounds of dust per day resulted in a cost of ⅗ cent per pound. This would be less than 4 cents a tree at the rate of use in the estimate given in this bulletin, at 4 applications a season. This is for the application alone, excluding materials. Our figures are respectively 27.8 cents for spraying, having an extra man and applying more per day, and about 5 cents a tree for dust, applying only 1500 pounds per day. These figures agree with those from Nova Scotia better than we might expect, in view of our limited data on the average costs of applications.

EXPERIMENTS AND OBSERVATIONS NOT CONFINED TO HIGHMOOR FARM

The Time of Ascospore Maturity

As pointed out in a previous bulletin (18, p. 175), "it has become apparent that the time of discharge of winter spores varies considerably from season to season in one place and from one place to another in one season, relative to the time of blossoming." As might be expected, it varies also with the calendar date. Since the discharge of ascospores or winter spores begins the seasonal activity of the disease, a knowledge of its beginning might be expected to indicate when spraying should be begun earlier than usual, or when it could be started later than usual.

As stated on p. 151 and in Table 2 of this bulletin, a comparison was made between dead scabby leaves from the 1924 season that were gathered from the ground at various places, regarding the maturity of ascospores (winter spores.) An unusually light snowfall during the winter and an early thaw permitted the gathering of leaves during the last of March. It is seen from Table 2 that mature ascospores were found in material gathered May 4 at Wiscasset, May 8 at Orono, and May 12 at Highmoor Farm. The number of leaves containing mature ascospores was small, being respectively for the dates and places mentioned 1 in 8, 1 in 19, and 1 in 28. This small proportion, together with their absence in a sample got later at Orono, indicates that the samples examined were too small to make them truly or necessarily representative. That is, it is quite probable that in the place where ascospore-free samples were got earlier than the dates given above, there were some uncollected leaves with ascospores already mature. Therefore no conclusions can be drawn as to whether one locality in Maine in 1925 was like another in respect to the time ascospores were mature or were causing the first infection. This will hold true in subsequent seasons until it is known how many leaves must be examined to be representative.

Diseased Twigs as a Source of Infection in McIntosh

Morse and Darrow (17) have discussed evidence from Maine and elsewhere as to young shoots being a source of spring infec-

tion by apple scab. From diseased twigs they secured viable conidia "up to about the first of May, or till about the time the leaf buds began to open," secured cultures that infected young apple trees growing in the greenhouse, and got only non-living spores after the twigs had been dipped for a few seconds in winter strength lime-sulphur (liquid, not dry). They also reported that a somewhat delayed dormant application of liquid lime-sulphur on part of a commercial orchard containing twig infection largely eliminated a severe attack of scab, "but no results of a regularly conducted spraying experiment were secured."

Scab on twigs of McIntosh apple trees is described by Morris as being common in Montana and as yielding living cultures as late as March, but "no data were secured as to what extent such twigs are a source of spring infection." (15, p. 70-73, illus. p. 72 and oppos. p. 69, the latter in color.)

Fraser (8) shows that in twig cankers, common in eastern Canada, conidiospores were being actively produced at about June 1. He refers to a reduction of loss from scab by spring pruning of the twig cankers, and reports experiments showing that even from over-wintering scabby apples, viable conidiospores can be obtained.

In England "the scabbed wood of certain varieties of apples . . . . is undoubtedly a prolific source of infection," although certain early outbreaks are to be attributed to the winter stage in the leaves, which was not reported there until 1924. (22, p. 547, 550.)

In 1924, further observations on a group of young McIntosh trees on the Maine Agricultural College farm showed that the first scab infection originated from scab pustules on the twigs. There were enough healthy leaves on healthy branches to indicate that ascospore infection was absent or negligible at the time of the observations described. There may have been some twig pustules, which sometimes affect too small an area to be easily found, that did not cause leaf infection, but leaf infection when present was severe, had occurred early, and was closely associated with twig pustules. The earliness of leaf infection was indicated by its being worse on the leaves' lower surfaces, which are of course exposed first as the leaves emerge from the buds. Most of the infected twigs became defoliated and died. A number of trees

were left unsprayed for experimental purposes and leaf infection became general during the summer.

Twig infection again occurred here, on the new 1924 growth of wood. On April 5, 1925, conidiospores from twig pustules from 8 trees had germination percentages respectively of 20, 24, 38, 39, 63, 70, 70, and 76 per cent, in hanging-drop microscopic mounts of distilled water. On April 9, 2 trees were given an application of 5-50 copper sulphate, 3 trees were given an application of dormant strength dry lime-sulphur (16-50), and the rest were left as controls. The method of applying the copper sulphate was thorough but the hand sprayer that was used did not work well with the lime-sulphur, which was not from a freshly opened container and which contained much insoluble material, apparently free sulphur.

Most of the scabby leaves had been removed in the fall of 1924 to other places for experimental purposes, and the trees in question were exposed to strong winds, so that in the spring of 1925 very few old apple leaves of any kind, and no scabby ones, were found nearby. This reduced the opportunity for ascospore infection, and furthermore the detailed examination of over 100 scabby leaves left outdoors over winter in this locality, disclosed scab perithecia on only 1 leaf (p. 154).

The leaves were emerging from some buds by May 14. By June 1 some leaves were 3 cm. long, but none were scabby. On June 13 no scab was noted on several hundred leaves examined at random, some being near to scab-cankered twigs. Most of the scabbed twigs were dead and had produced no leaves. The next examination was made on July 3, when a high correlation between twig pustules and scab on the leaves was seen. Some of the scab infection on the leaves evidently had occurred somewhat earlier than the rest, being severe on the lower surfaces of leaves near to comparatively small pustuled areas in the twig bark. The rest of the infection was on the upper leaf surfaces and much of it was at a greater distance from pustules. However, practically all scabby leaves were on the same level with twig pustules, and not more than about 4 inches distant, except for some farther away but below pustules and so in the line of dripping water. In several instances a few scabby leaves were among healthy ones, but in each case search revealed one to several of the small individual pustules as being situated above or nearby.

The preceding observations were made in a nursery. Observations were also made a few days later in an orchard of the same variety about a mile distant. This orchard had been under the observation of A. K. Gardner, the extension specialist of the Agricultural College in charge of horticultural projects, who stated that the trees were about 35 years old and that they had not received the pre-pink spray and also had not received the calyx spray as early as possible. Here infection was severe in some places but was centered around solitary lesions on the lower surfaces of the first-formed leaves, apparently primary ascospore infections, and no twig infection was observed. A fundamental difference between these infections and those coming from twig pustules, is that the oldest leaf infections when coming from ascospores were much less extensive and severe than those com-

TABLE 13.

Effect of dormant spraying on spring infection from diseased twigs. Orono, Maine, July 3, 1925

Tree No.	Spray	Branch		Leaves		Remarks
		No.	Twig pustules	Number examined[1]	Percentage scabby	
1	None	1	Several	85	40	Infection worse than on sprayed trees
		2	Do	90	39	
		3	None	63	0	
		4	2 Small	70	4	Scabby leaves between pustules and ground
2	Do	1	Nearby	60	23	
		2	None near	65	4	
3	Copper sulphate	1	Nearby	21	14	
		2	None	95	0	
4	Do	1	Several	75	11	All scabby leaves near pustules
		2	None	36	0	
		3-A	Present below	60	0	Branch divided into (A) part above pustules and (B) part below them
		3-B	Present above	36	14	
5	[illegible] sulphur	1	Several	80	25	All scabby leaves near pustules
		2	None	50	0	
		3	One	50	2	Scabby leaf the lowest one, near pustule
		4-A	Present below	95	1	1 scab spot
		4-B	Present above	19	42	1 to several scab spots per leaf — Branch divided into (A) part above pustules and (B) part below them
6	Do	1	Present	30	73	
		2	Do	100	54	

[1]All leaves of a branch examined.

ing from twig pustules, presumably because of a difference in the number of spores per leaf causing the primary infections.

The results of the observations in the nursery are illustrated in Table 13 by counts. There the correlation between twig pustules and leaf scab is shown clearly. Also, copper sulphate spraying apparently had some effect, although it did not eliminate the leaf scab, while the dry lime-sulphur had no effect. The original spore germination percentage was high for the copper-sulphate sprayed trees. Time was not available for a test of the viability of the spores and spore-producing mycelium in the twig pustules following the spraying. Such a test, in case of nonviability, to be significant would require satisfactory proof that no copper sulphate or lime-sulphur constituent was present with the tested material at the time of testing.

The negative results from the dry lime-sulphur spraying and the incomplete effects of the copper sulphate spraying still leave it probable that with higher pressure, or with liquid lime-sulphur, better results could have been obtained.

Severity of Scab on Highmoor Farm Compared with that Elsewhere

Of a half-dozen Ben Davis orchards visited, mention may be made of one that had no scab apparent yet at about the middle of August, following 4 sprayings according to the owner's statement, and, at the other extreme, of another where about half of the fruits were obviously scabby at that time, the method of treatment being unknown.

Following each spray application on the experimental Ben Davis plots except the prepink, an application was also made on an orchard of 12-year old McIntosh trees set out for a certain horticultural experiment, according to those in charge of the spraying of this orchard. In addition a delayed dormant application is said to have been made. At about the middle of August only a trace of scab could be seen on about 1000 of the fruits as examined unpicked on the trees. After picking, several hundred fruits were sorted and about 5 per cent were found to be scabby. About as many more were inconspicuously scabby, according to a careful inspection of a sample of 100 fruits. These fruits were highly colored and were not at all russeted.

Similar sorting of less highly colored McIntosh fruits from larger trees in another orchard, said to have received the same treatment, showed that about 50 per cent were scabby.

Several orchards visited during the summer ranged from one with about 10 per cent of the fruits obviously scabby as seen on the tree at about the middle of August, to one with practically every fruit scabby, in spite of two sprayings (according to the owner).

It seems that scab was worse on McIntosh than on Ben Davis, in general as well as on Highmoor Farm.

STORAGE EXPERIMENTS AS TO INFECTION, SPREAD, AND ENLARGEMENT OF SCAB LESIONS

Mention was made, in the previous section of this bulletin on the sorting of the fruits for scab, of inconspicuous spots "about as small as a pinhead or pinprick, or even spots young enough to be in the blister stage with no dark scab spores showing." (See Fig. 19.) From past observations made by others, it was thought possible that further development of scab might occur in storage. Hence some attention was paid to marking the spots on certain apples and to observing them in storage to see whether some conditions more than others favored the further development of scab.

Wallace (25, p. 574-576) summarizes the literature and his own observations, proposing as possibly contributing to the storage-scab difficulty the following: weather favorable for infection on the tree just previous to picking; lodging of spores on the fruit at picking time or before, and infection during storage; scattering of the spores and infection during storage; in all cases, a delay of the appearance of the scab spots until after some time in storage. Hesler and Whetzel (11, p. 11) state that "if fruits are inoculated just prior to picking, the spots appear in storage." A still more recent general statement is that "scab sometimes continues to develop in storage, but the characteristics of the spots are quite different from those found at picking time. They are smooth, black, and sunken, sometimes attaining a diameter of one-fourth of an inch before the fungus breaks through to the surface or causes any roughening of the skin. The development of the scab fungus is checked by low temperatures and ordinarily makes

little trouble in cold storage except as a source of rot infections" (3, p. 4).

The first instance recorded in Maine was observed during the winter of 1907-08. (16, p. 4). The trouble was common but was considered abnormal, and was explained on the basis "that the entire growing and harvesting season was very wet, and the vegetative development of the fungus continued up to and during the harvest time. The moist apples, covered with spores, were then placed in rather warm cellars, resulting in the infection of the fruit and the formation of the small scab spots in storage." In another instance "the evidence plainly indicated spread in storage. In a box of very clean No. 1 McIntosh, packed for perfect apples, one bearing a medium sized scab spot covered with spores was placed by accident. This box was placed in a relatively cool but quite moist cellar and when opened by one of us in mid-winter several apples lying immediately below the summer-scabbed apple were covered with the small black spots above described. The remainder of the fruit in the box was without blemish of any kind.

"Directions for the control of apple scab by spraying will be found on p. 390. Fruit from trees that are well sprayed will be less likely to develop the disease in storage. Scabby apples should be carefully sorted from the sound before storing. The temperature of storage should be as low as consistent with safety and not subject to abrupt changes. Very moist storage conditions should be avoided." (19, p. 355.)

EXPERIMENTS AT ORONO

In the experiments to be described here, Ben Davis and McIntosh apples were subjected to different combinations of environmental conditions. The temperature in the various storage chambers averaged about 45, 60, 70, 75, and 85° F. respectively. The coolest chamber was continuous with the ice chamber which was above it so that air circulation was maintained through the effect of gravity on the chilled air. The mean in this chamber (about 8° C.) varied with the time of the reading of the thermometer and with the location of the thermometer read, the thermometers being standardized, and fluctuation being from 3.5 to 12.0°C. The next coolest chamber (mean about 15°C., with extreme recorded range of from 13.4 to 17.7°C.) was cooled by means of a

coil containing water from the melting ice and was warmed by an automatic electrical heating device. The other chambers were cooled by the room air which was kept continuous with that outdoors, and were heated electrically. They fluctuated a little less (respectively, mean about 20°C., range from 19 to 23°C.; mean about 25°C., range from 24 to 26°C.; mean about 31°C., range from 29.8 to 31.8°C.)

In each of these five temperature chambers there were placed apples from three sources, namely, (1) clean or scab-free as far as careful ocular examination could disclose, (2) clean but rubbed against a wet scab spot, and (3) with one or more scab spots evident. No fungicide was used on these fruits at any time during growth or storage. Germination tests of inoculum from similar scab spots gave percentages of from 3 to 40 per cent living spores.

From each source, in each temperature chamber, several apples were kept in a glass jar with no cover, and several in a covered glass jar with free water inside to keep the air moist.

TABLE 14.

Effect of time of observation on the development of scab in experiment at Orono, winter of 1925-1926[1]

Variety	Period of time	Temperature °F.					Temperature °F.					Temperature °F.				
		45	60	70	75	85	45	60	70	75	85	45	60	70	75	85
		No. of apples					Ave. no. of new spots per apple					Percentage of apples with new spots				
Ben Davis	I	22	22	21	22	23	0.5	0	0.3	0.2	0.4	5	0	10	9	4
	II	25	25	25	25	25	1.2	2.3	3.9	2.1	1.2	44	52	64	56	24
	III	25	24	19	19	23	2.2	3.9	1.0	1.4	0.7	72	46	32	42	44
	I-III	25	25	25	25	25	3.4	6.0	4.8	3.3	1.8	76	68	68	68	52
Mc-In-tosh	II	25	25	22	25	24	1.4	8.5	6.4	3.7	2.4	16	32	32	20	13
	III	22	16	7	9	9	5.7	11.2	12.4	0 9	0.7	32	56	43	33	11
	II-III	25	25	22	25	24	5.6	15.6	10.3	4.0	1.8	28	48	36	28	17

[1] For a description of the details of this experiment see p. 191 and ff. in the text.

Altogether there were, therefore, 30 jars of each of the two varieties. As each apple was examined, each scab spot was encircled with India ink, many being marked in such a way that subsequent enlargement of the spots could be detected. Some of the Ben Davis apples were examined on October 18 at Highmoor Farm, and the experiment was begun on October 24. The appear-

TABLE 15.

Effect of storage conditions on the development of scab in experiment at Orono, winter of 1925-1926[1]

Variety	Temperature	Period of time	No. of apples						Ave. no. of new spots per apple						Percentage of apples with new spots					
			Clean		Inoc.		Scabby		Clean		Inoc.		Scabby		Clean		Inoc.		Scabby	
			D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M
	°F.																			
Ben Davis	85	I-III	4	4	4	5	4	4	4.0	0	1.5	0.6	0.8	4.5	75	0	75	20	75	75
	75	do	4	4	4	5	4	4	0.5	1.5	5.3	3.2	4.5	4.8	25	75	75	60	75	100
	70	do	4	4	4	5	4	4	0.5	3.0	3.5	7.6	4.5	9.3	25	100	50	100	75	50
	60	do	4	4	4	5	4	4	3.8	3.3	4.0	1.0	19.5	5.8	100	75	25	40	100	75
	45	do	4	4	4	5	4	4	0.8	2.8	5.8	2.8	3.5	5.3	25	75	75	80	100	100
	45-85	I	20	20	20	25	11	14	0	0	0	0	0.8	0.2	0	0	0	0	27	21
		II	20	20	20	25	20	20	0.7	1.5	1.6	2.3	2.2	4.5	20	55	40	44	65	65
		III	19	16	20	24	16	15	1.3	0.8	2.4	0.7	4.9	1.7	53	38	50	29	75	53
		I-III	20	20	20	25	20	20	1.9	2.1	4.0	3.0	6.6	5.9	50	65	60	60	85	80
McIntosh	85	II-III	4	4	4	5	4	3	1.5	0	0	0	6.8	3.3	25	0	0	0	50	33
	75	do	4	4	4	5	4	4	0	0	0.8	0	14.3	10.0	0	0	50	0	50	75
	70	do	4	3	4	4	4	3	1.3	0	2.3	0	50.0	4.3	50	0	25	0	50	100
	60	do	4	4	4	5	4	4	0.3	2.0	6.5	0.2	82.5	6.3	25	25	50	20	100	75
	45	do	4	4	4	5	4	4	1.3	1.0	0	0.6	8.3	23.8	25	25	0	20	50	50
	45-85	II	20	19	20	24	20	18	0.2	0.4	1.2	0	19.5	5.1	5	5	10	0	60	61
		III	15	7	15	11	10	5	0.9	0.6	1.0	0.4	25.7	18.2	27	14	33	18	70	80
		II-III	20	19	20	24	20	18	0.9	0.6	1.9	0.2	32.4	10.2	25	11	25	8	60	67

[1]For description of the details of this experiment see p. 191 and ff. in the text.

ance of new scab spots during this first period or interval in some Ben Davis is included in Tables 14 and 15, but can be readily distinguished from the results got in storage in the second interval (October 24 to November 12) or the third (November 12 to January 7).

Some of the scab lesions enlarged slightly. Usually they did not (Figs. 16-18). The greatest increase in size was relative, where spots of the pin-prick size became as large as pin-heads. It was more common to find still larger spots that had not been marked at the previous examination. Sometimes these spots had an effect on the photographic plate at the first examination even when not detected by the eye (Figs. 19 and 20). Often the new spots apparently belonged to the same cluster as had been seen previously. Thus, 50 spots on one apple might be increased to 100 spots on the same cheek within three weeks while other parts of the same apple and other apples in the same chamber showed no increase. This suggests that in the first case infection had been severe, with the incubation period longer for some spots than for others just as in inoculated leaves of greater maturity (see p. 162).

The summary of results as given in Tables 14 and 15 justify certain conclusions. In Ben Davis, the highest temperature gave the fewest new spots, gave the lowest percentage of apples showing new spots, and gave a slower appearance of spots as expressed in the percentage. Lower temperature down to 60° F. gave more new spots per apple. The two lowest temperatures gave a delay in the time of appearance of new spots, and the lowest temperature gave the highest percentage of apples with new spots. This indicates that more spots could have been expected at the lowest temperatures had the experiment been carried on longer. In fact, additional spots were found at later examinations in February and again in March.

Comparing the dry (D) with the moist (M) chambers, with other conditions similar the only significant difference seems to be in a slower appearance of new spots in the dry chambers. The clean apples showed the least number of new spots per apple. The scabby apples showed the greatest number and also the highest percentage of apples with new spots. This suggests that scab spots already present on the apple favored new infection, possibly due to the infection occurring while the apples were on the tree.

before being brought together during the operations of picking and packing.

The McIntosh matured earlier than the Ben Davis and many rotted. In this variety, the highest temperature gave the lowest number of new spots per apple, gave the lowest percentage of apples showing new spots, and gave an earlier appearance of the spots. With a lower temperature down to 45°F., there were more spots per apple and a higher percentage of apples showing new spots. In the dry chambers, as against the moist, there were more new spots per apple, especially in the inoculated and scabby groups, and a higher percentage of apples showing new spots in the clean and inoculated groups. The scabby apples had many more spots per apple and a much higher percentage of fruits showing new spots, than the clean and inoculated apples.

Experiments at Highmoor Farm and at Portland

At the same time that the Ben Davis apples were selected for the Orono experiments, others were packed in barrels following commercial methods with certain modifications. Marked scabby apples were placed in certain parts of some barrels in order to test the possibility of spread from one apple to another at or after the time of packing. The apples in some barrels were wet by dew and by sprinkled well-water before being packed. Six barrels were placed in cold storage[3] during the last part of October and at the same time three were placed in cellar storage at Highmoor Farm. Seven of these barrels were opened on January 19 to 21 and the apples sorted by the writer by layers usually of 50. The results are given in Table 16.

In Barrel No. 1, packed dry and kept in cold storage, from 20 to 32 per cent of the fruits were scabby although packed as clean, but there was no increase of percentage with proximity to the scabby layers at the ends and middle. Furthermore, in similar clean stock packed by itself in Barrel No. 3, from 22 to 36 per cent of the apples were scabby that came from one source, while from another source, probably the inoculated tree of Table 4, from 34 to 78 per cent of the apples were scabby in spite of an

[3]In the New England Cold Storage Co. plant in Portland, where free accommodations were furnished in a room kept at 31½ to 36½°F.

TABLE 16.

Effect of packing and storage conditions on the development of scab in storage at Highmoor Farm and at Portland, winter of 1925-1926

Barrel No.	Condition of packing and storage	Examination on January 19-21			
		Layer No.	Source of apples	No. of apples	Apples scabby
					%
1	Packed dry, kept in cold storage	1	Scabby when packed	23	100
		2	From unsprayed trees, clean when packed	50	28
		3		50	30
		4		50	30
		5		50	24
		6		50	32
		7		50	28
		8		50	26
		9	Scabby when packed	28	100
		10	From unsprayed trees; clean when packed	50	30
		11		50	24
		12		50	20
		13		69	28
		14	Scabby when packed	25	100
3	Packed dry, kept in cold storage	1	From unsprayed trees; clean when packed	50	36
		2		50	36
		3		50	22
		4		50	26
		5		50	36
		6	From unsprayed trees; double-inspected clean when packed	37	32
		7		50	70
		8		50	56
		9		50	34
		10		50	54
		11		50	78
		12		64	61
4	Packed dry, kept in cellar storage	1	From unsprayed trees; clean when packed	50	80
		2		50	66
		3		50	58
		4		50	38
		5	From unsprayed trees; double-inspected clean when packed	50	28
		6		76	29
		7		50	50
		8		50	52
		9		50	48
		10		50	58
		11		83	66
5	Packed wet, kept in cold storage	1	Scabby when packed	14	100
		2	From unsprayed trees; double-inspected clean when packed	50	56
		3		50	40
		4		60	40
		5		50	32
		6		50	28
		7	From unsprayed trees; clean when packed	50	34
		8		50	18
		9		50	34
		10		50	18
		11		50	22
		12		50	20
		13		80	36
		14	Scabby when packed	25	100

Effect of packing and storage conditions on the development of scab in storage at Highmoor Farm and at Portland, winter of 1925-1926—Concluded.

Barrel No.	Condition of packing and storage	Examination on January 19-21			
		Layer No.	Source of app'es	No. of apples	Apples scabby
					%
		1	Scabby when packed	24	100
		2	From unsprayed trees; double-inspected clean when packed	66	47
		3		50	30
		4		50	38
		5		50	36
		6		50	36
6	Packed wet, kept in cellar storage	7	From unsprayed trees; clean when packed	50	32
		8		50	30
		9		50	34
		10		50	34
		11		50	36
		12		50	42
		13		44	41
		14	Scabby when packed	22	100
		1	Scabby when packed	29	100
		2		50	0
		3		50	2
		4	From sprayed trees; clean when packed	50	2
		5		50	4
		6		50	0
8	Packed dry, kept in cold storage	7		50	2
		8		20	0
		9	Scabby when packed	36	100
		10		50	0
		11	From sprayed trees; clean when packed	50	2
		12		50	2
		13		50	0
		14		71	0
		15	Scabby when packed	24	100
		1	Scabby when packed	37	100
		2		50	8
		3		50	8
		4		50	0
		5		50	10
		6	From sprayed trees; clean when packed	50	6
9	Packed wet, kept in cold storage	7		50	6
		8		50	10
		9		50	22
		10		50	16
		11		50	14
		12		65	17
		13	Scabby when packed	23	100

additional careful examination given just before being packed. In Barrel No. 4, which was like Barrel No. 3 except for being kept in cellar storage, from 28 to 80 per cent of the apples were scabby with a tendency for the percentage to increase with proximity to each end, especially the upper end.

In Barrel No. 5, packed wet and kept in cold storage, the stock that had received an additional examination at packing time

had more scab than the other apples packed as clean, but there was no significant increase of scab in the layers next to the scabby layers, judging from the variation in layers 7 to 10. In Barrel No. 6, which was like Barrel No. 5 except for being kept in cellar storage, similar results were obtained.

In Barrel No. 8, packed dry and kept in cold storage, such variation as occurred was not correlated with proximity to the scabby layers, and the sprayed clean apples showed much less scab than the unsprayed clean apples in Barrels 1 and 3. In Barrel No. 9, like No. 8 except for being packed wet, there was again an absence of effect from proximity to scabby apples, but there was somewhat more scab. This might possibly be due to a different source of the fruits, these coming from a tree which was not sprayed quite so thoroughly, or might be due to the scab spots appearing earlier in wet conditions at the low cold storage temperature. (See p. 194.)

In this experiment the new scab spots appeared larger in the cellar storage barrels than in corresponding barrels kept in cold storage. In either kind of storage it was common to find a fruit packed as scabby having a diseased face next to a clean face of another apple. No significant grouping of scabby apples was observed. Apparently the conditions of this test were not favorable to a spread of scab from one apple to another at or after packing time, so that the most important factor in the development of scab in storage was the source of the fruit that was packed as clean. That is, spraying and its control of scab during the growing season was more important than proximity to diseased fruit in the barrel, or than conditions of moisture at packing and of temperature during storage. Moisture and temperature had some effect, however, in the development of scab, probably through the effect on infection already present at packing but not yet showing at that time, rather than through any new infection occurring in storage.

As in the storage experiment at Orono, new spots developed on apples packed as scabby (Fig. 21, at top).

DISCUSSION AND GENERAL CONCLUSIONS

Sufficient attention has been given in preceding pages to a discussion of a possible cumulative effect of fungicides, of a cause of difficulty of scab control in the McIntosh variety, and

of the development of scab in storage. Work on these problems has not progressed far enough yet in this State to make it advisable to present definite general conclusions. Two of our chief problems in this work, however, can be discussed more fully with profit, namely, the seasonal adaptation of schedules, and substitutes for liquid lime-sulphur.

The Seasonal Adaptation of Schedules

The conception of timing the first application according to the beginning of activity of the scab disease has already been mentioned. Altogether there are several possibilities. The ascospores may be mature and present in abundance, or else scarce. Scarcity is exemplified in the results secured here in the study of the time of maturity in 1925 (see p. 151). Abundance is exemplified by the filtration from orchard air of 289 ascospores per cubic foot of air (or one ascospore to every 6 cubic inches of air) as was done for 4 hours in Wisconsin on May 13, 1923 (13). The ascospores may be ripe for discharge and not get the rain necessary to bring them out. They may get the rain and be discharged without the proper conditions existing for infection of the leaves. They may infect, with the disease on the leaves then burned out by spray or with its spread checked by unfavorable weather, as at Highmoor Farm in 1924 (18, p. 145). Finally, the ascospores may not become mature early.

These various possibilities make it at least difficult to foretell the value of a delayed dormant or pre-pink application, or even of a pink, for a given season. Eventually this may be possible on the basis of observations on the current weather, but at present the best basis is observations on the ascospores. The usefulness of such observations is often restricted to a locality. In Ohio in 1924, in one place scab was not important, in two places three pre-blossom applications were needed, in one place a warning as to the need of a pre-pink application was needed for control, and in two places scab control was got following the advice that the pink application was the only one needed before blossoming. (20, p. 28-30).

In Delaware in 1922 and 1923, "the maximum period of spore discharge for the two years occurred during May in Kent County and during April in Sussex County." These are adjacent counties in the smallest state in the Union. "The later and smaller dis-

charge of ascospores in Kent County is associated with the later maturing of the perithecia [containing the ascospores] in relation to temperature and rainfall." "It is not considered that annual ascospore discharge studies would prove a practical guide for predicting spray applications because of the extreme variation in weather found locally and generally in the two counties." "It would be impossible to establish sufficient stations for spore discharge to take care of the variable local and general weather conditions in the two counties." "Thoroughly protecting the early progressive growth development is the most an orchardist can expect to accomplish." (1, p. 10, 15, 16.)

Some explanation of differences found with the season and locality is suggested by the results of work in Wisconsin. There "a marked relationship was observed between the time of leaf-fall and ascospore maturity. Under the conditions studied, ascospores matured much earlier in leaves which fell in early autumn than in those which remained on the tree until late autumn or early winter. . . . . .Temperature and moisture were shown to be factors of cardinal importance in determining the rate of development of ascocarps" (14). Also, infection by the ascospores required only 6 hours of continuous wetting at a temperature of about 68°F. (20°C.) while it required 18 hours at a temperature of about 42°F. (6°C.) (12).

In conclusion, the seasonal adaptation of spraying through expert advice probably is good as far as it goes, but it often does not go far enough because of differences between localities. Its usefulness requires group grading of the fruit and the comparing of the results of grading, for practical proof. It also requires a highly concentrated apple industry and intensive use to be worth the cost.

SUBSTITUTES FOR LIQUID LIME-SULPHUR

From the results presented in a former publication (18, p. 165) it may be concluded that dry lime-sulphur when used at the 4-50 rate is practically as effective against scab as the liquid. The 1925 results at Highmoor Farm confirm this conclusion and also show that even on Ben Davis the difference in russeting is not always significant. The cost has been shown to be slightly greater at Highmoor Farm, when no account is made of leakage or the trouble of storage of the liquid.

In the preceding bulletin on apple spraying (18, p. 182) it was concluded that "with our present knowledge and materials it would seem that with the same number of applications there is more chance for disappointment in trying dusting than in trying spraying for the control of apple scab in Maine, though apparently there is a chance for success with both methods under some conditions." The 1925 results at Highmoor Farm confirm this conclusion, and show that with more applications, even with less sulphur applied each time, better control of scab can be obtained. Copper dust controlled scab little if at all and caused much russeting, as well as leaf-burning.

It was concluded previously (18, p. 184) that "the chief value of a casein spreader seems to be in a reduction of the amount of russeting on the fruits of certain susceptible varieties." This effect was not apparent in the 1925 tests on Highmoor Farm with Ben Davis which is easily russeted.

The conclusions referred to in the preceding paragraphs were drawn with the results of many published reports in hand. A few reports that are more recent will also be referred to in the following paragraphs.

As the result of extensive tests made in Pennsylvania in 1919 to 1923 inclusive, it is concluded that "of all the materials tested, lime sulphur, either home-made or commercial, used at the proper dilutions and properly applied, still holds its place as the standard fungicide for scab control." Also, that dry lime sulphur "gave much less foliage burning and fruit russeting than commercial liquid lime sulphur and equally as good control" of scab, that copper dusts are inferior to the sulphur dusts, that the latter are giving increasingly better results, and that a casein spreader does not increase the fungicidal value of lime sulphur. (24, p. 19-20.)

In Michigan, dusts have proven to be good substitutes in average seasons but are not consistently satisfactory in seasons of severe injury by disease. Favorable conditions are less frequently met there for dusting than for spraying, and more frequent applications are advised for dust. Dusting produces less foliage injury and gives a better finish to the fruit. Dry lime-sulphur at 4 pounds to 50 gallons is recommended as the equivalent of the liquid form at 1 gallon to 50. (6, p. 26).

As has been pointed out in a preceding section of this bulletin (p. 165), work in New York showed that sulphur applied as dust did not adhere as well as sulphur derived from lime-sulphur

spray, that Kayso increased the adherence of sulphur derived from lime-sulphur spray somewhat during the first week after application but not afterwards, and that probably sulphur is more effective as the particles are finer.

A more detailed discussion of spreaders is given by Robinson (21, p. 71, 77, 78, and 80), repeated in part as follows:

"An ideal spreader should cause a continuous film of the poison to be deposited on the surface covered instead of collecting in drops, it should increase adherence, it should not react chemically with the poison to form by-products that would cause foliage injury, it should not diminish the toxic properties of the poison, and it should not cost too much. The difficulty in selecting a spreader with these requirements is increased by the fact that the plant may have several different kinds of surfaces. For example, the apple tree has the smooth upper leaf surface, the hairy under leaf surface, and the waxy surface of the partially developed fruit; and in addition it may have the smooth bark and the wrinkled bark of spurs and the young and old leaves which may offer resistance in various ways to the spray. . . . It was also noticed that the age and exposure of the leaf to the sun's rays influenced the degree of spreading.....The surfaces changed throughout the growing season. This change in surface, whether leaf or fruit, probably accounts for contradictory results obtained by different workers using the same kind of spreader.....

"The use of spreaders for general orchard sprays has become more prevalent during the last few years. The development of the commercial casein-lime product has contributed mainly to this increase. Questions regarding the advisability of using spreaders, the kind to use, and the concentration that will give best results can be answered satisfactorily only when all conditions are taken into consideration. The cost is perhaps the most important point to consider. If the cost is low, spreaders may be used advantageously in most sprays, but if they are as high as present prices that prevail for the commercial casein-lime it should be used only for those sprays that unquestionably are improved by it and when beneficial results are obvious.....

"Considering price, skim milk and skim-milk products have proved to be excellent substitutes for the commercial casein-lime spreaders. Laboratory tests and limited field experiments indicate that when skim milk is used at the rate of 2 to 3 quarts to 100 gallons it spreads well over many surfaces such as apple, pear, prune, peach, cherry, and cabbage leaves, and apple and pear fruits. The dried product used in equivalent amounts, as at the rate of solids in skim milk or 2.5 ounces to the quart, and the partially dried clabbered milk such as is used for stock feed, give equally good results. It is necessary to add a few ounces of hydrated lime or slaked quicklime to each quart of sweet skim milk and larger amounts to the commercial stock foods in order to neutralize the acidity and to bring the proteins into colloidal solution. Unless the lime is added spreading will not result. Skim milk, the dried or condensed skim milk, and the clabbered product are brought into solution easily, and in this respect they are preferable to the commercial

casein-lime that must be worked carefully to a paste before putting into the spray tank in order to get best results.....The amount of lead arsenate that adhered was generally higher on the leaves where a spreader had been used than where lead arsenate only had been applied. Skim milk, apparently, was as good as the casein-lime spreaders. It spread well and formed a good even coating of the poison on the leaf surface.....The amount of spreader to use for best results is an important phase of the work and must be decided by field observations. Many variable factors that exist at the time of application should be taken into consideration and the amount of spreader used should be controlled accordingly. The pressure or force used, the kind of surface to be covered, the type of gun or nozzle used, and the climatic conditions, may influence the amount of spreader that will give best results. Too much spreader may cause excessive drip if sprayed to the drenching point. On the other hand, drenching with good force with a minimum amount of spreader is advisable. Most of these points should be definitely settled by field observations."

Apparently, then, it is still doubtful how much lime-sulphur can be dispensed with through the use of a casein spreader.

Young (26, p. 133) states that:

"The more finely divided sulphurs.....were more easily oxidized and were therefore more active as fungicides at temperatures and conditions at which the flowers, or flour, of sulphur exhibited toxicity to only a very slight degree.....The need for a more active sulphur summer spray is urgent, in that lime-sulphur, because of foliage injury, is so frequently unsafe even on apple."

In conclusion, lime sulphur has not yet been displaced as the material to be the most generally preferred, though work is being continued to develop a more suitable means of controlling scab.

Literature Cited

(1) Adams, J. F. The spore discharge of the apple scab fungus in Delaware. Delaware Agr. Exp. Sta. Bul. 140. 1925.

(2) Brittain, W. H. Methods employed in recording results of spraying and dusting experiments in apple orchards. Sci. Agric. 4: 141-151. 1924.

(3) Brooks, Charles, J. S. Cooley, and D. F. Fisher. Diseases of apples in storage. U. S. Dept. Agri. Farmers' Bul. 1160. Revised 1924.

(4) Butler, O. Control of apple scab. New Hampshire Agr. Exp. Sta. Circ. 25. 1925.

(5) Doran, W. L. Experiments on the control of apple scab and black rot and spray injury in 1924. Massachusetts Agr. Exp. Sta. Bul. 222. 1925.

(6) Dutton, W. C., R. H. Pettit, C. W. Bennett, and H. A. Cardinell. Spraying calendar. Michigan Agr. Exp. Sta. Special Bul. 140. 1925.

(7) Fitch, H. W. Quantitative determination of sulfur fungicides on foliage. Phytopathology 15: 351-354. 1925.

(8) Fraser, W. P. Overwintering of the apple-scab fungus. Science N. S. 46: 280-282. 1917.

(9) Frey, C. N., and G. W. Keitt. Studies of spore dissemination of Venturia inaequalis (Cke.) Wint. in relation to seasonal development of apple scab. Jour. Agric. Res. 30: 529-540. 1925.

(10) Grubb, N. H. Tests of fungicides on apple trees.—II. An analytical study of their effects on the trees. Jour. Pomol. and Hort. Sci. 3: 157-173. 1924. (As abst. in Exp. Sta. Rec. 52: 848. 1925.)

(11) Hesler, Lex R., and Herbert Hice Whetzel. Manual of fruit diseases. xx & 462 p. MacMillan Co., New York. 1917.

(12) Keitt, G. W. Studies of apple scab infection under controlled conditions. (Abst.) Phytopathology 16: 77. 1926.

(13) Keitt, G. W. and L. K. Jones. Frequencies of ascospores of Venturia inaequalis in orchard air. (Abst.) Phytopathology 15: 57. 1925.

(14) Keitt, G. W., and E. E. Wilson. Studies on the development of the ascigerous stage of Venturia inaequalis in nature. (Abst.) Phytopathology 16: 77. 1926.

(15) Morris, H. E. A contribution to our knowledge of apple scab. Montana Agr. Exp. Sta. Bul. 96. p. 69-102. 1914.

(16) Morse, W. J. Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164. 1909.

(17) Morse, W. J., and W. H. Darrow. Is apple scab on young shoots a source of spring infection? Phytopath. 3: 265-269. 1913.

(18) Morse, W. J., and Donald Folsom. Apple spraying and dusting experiments 1918 to 1924. Maine Agr. Exp. Sta. Bul. 325. 1925.

(19) Morse, W. J., and C. E. Lewis. Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185. 1910.

(20) Ohio Agr. Exp. Sta. 43rd Ann. Rpt. Bul. 382. 1924.

(21) Robinson, R. H. Spreaders for spray materials, and the relation of surface tension of solutions to their spreading qualities. Jour. Agr. Res. 31: 71-81. 1925.

(22) Salmon, E. S., and W. M. Ware. Apple and pear scab. Jour. Min. Agric. Great Britain 31: 546-554. 1924.

(23) Thatcher, R. W., and Leon R. Streeter. The adherence to foliage of sulfur in fungicidal dusts and sprays. New York State (Geneva) Agr. Exp. Sta. Tech. Bul. 116. 1925.

(24) Thurston, H. W., Jr., R. C. Walton, and F. N. Fagan. Comparison of materials used in spraying and dusting for apple scab control in Pennsylvania. Pennsylvania Agr. Exp. Sta. Bul. 190. 1924.

(25) Wallace, Errett. Scab disease of apples. New York (Cornell) Agr. Exp. Sta. Bul. 335. 1913.

(26) Young, H. C. Colloidal sulphur as a spray material. Ann. Missouri Bot. Gard. 12: 133-143. 1925.

(27) Young, H. C., and R. C. Walton. Spray injury to apple. Phytopathology 15: 405-415. Plate 14 (colored). 1925.

(28) Zappe, M. P., and E. M. Stoddard. Summary of five years work on spraying and dusting. In 24th Rpt. State Entom. Connecticut. Conn. Agr. Exp. Sta. Bul. 265. 1925. p. 293-294.

Fig. 16. At top, Ben Davis apple with several scab spots of which the central large one is probably the oldest with the others arising later from spores washing from the oldest spot. These spots in the aggregate covered an area larger than a dime and so were enough to disqualify even for the B grade. Photographed on October 27, 1925, reduced somewhat in size. At bottom, the same apple photographed on January 12, 1926, after 11 weeks in cold storage. No enlargement of the scab spots has occurred, but there has been some withering around the spots. (The new disfigurement in the upper right hand part is due to a bruise, already faintly apparent in the photograph on the left.)

Fig. 17. At top, Ben Davis apple cracked and distorted as the result of severe scab infection. Photographed on October 27, 1925, reduced somewhat in size. At bottom, the same apple photographed on January 12, 1926, after 11 weeks in cold storage. The scab spots have not enlarged but have caused marked withering. See Fig. 18, at bottom, for unwithered apple of same lot.

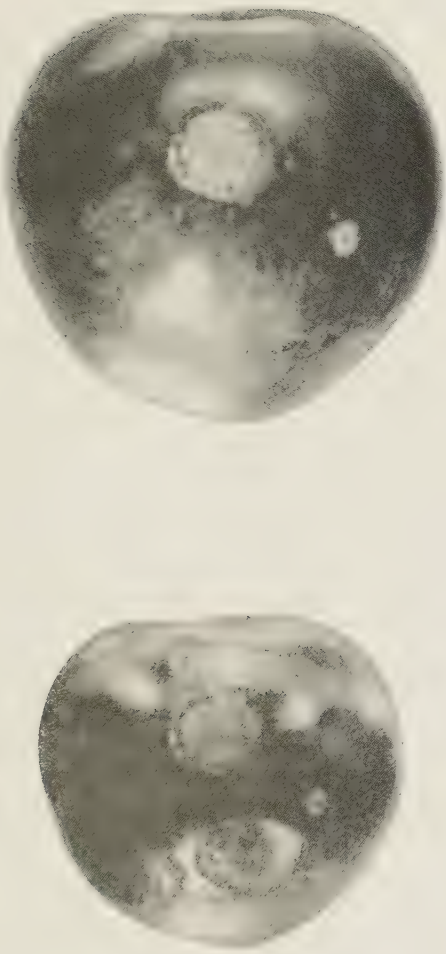

FIG. 18. At top, Ben Davis apple with a large, partly healed scab spot and a smaller spot probably resulting from a later infection. Photographed on October 27, 1925. At bottom, the same apple photographed on January 12, 1926, after 11 weeks in storage. The two scab spots have not enlarged. (Several bruises have become apparent.)

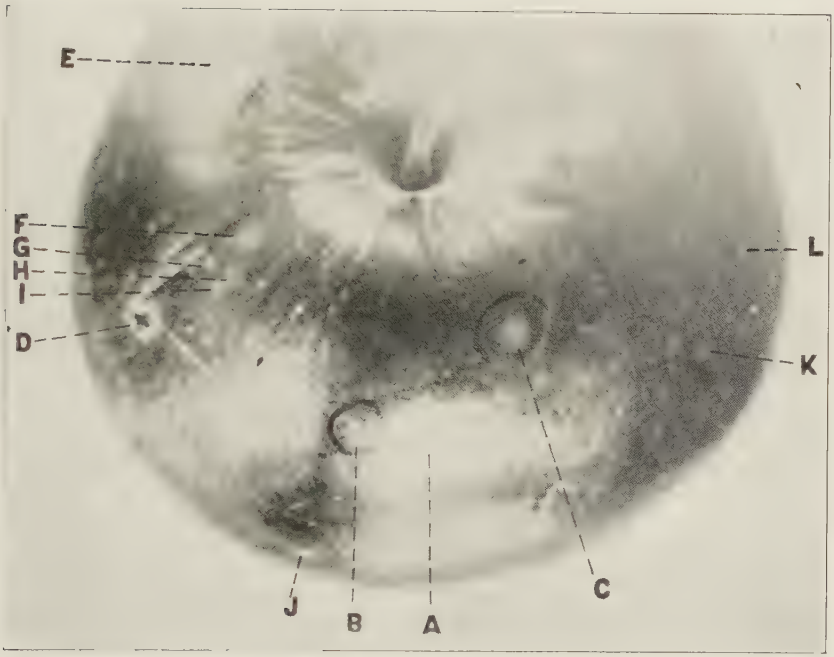

Fig. 19. Photograph of a Ben Davis apple taken on October 27, 1925, to show the early blister stage of scab spots that appear late in the season. The ink ring around the blister marked A appears white by the reflected light used to bring out the blister in the photograph. The two other ringed spots marked B and C were of about the same stage as the one marked A. No other scab spot was detected at this time except the one marked D, which had broken the skin, and E. Enlarged here nearly two times. See Fig. 20 for appearance after 11 weeks in cold storage and for explanation of the spots marked F to L.

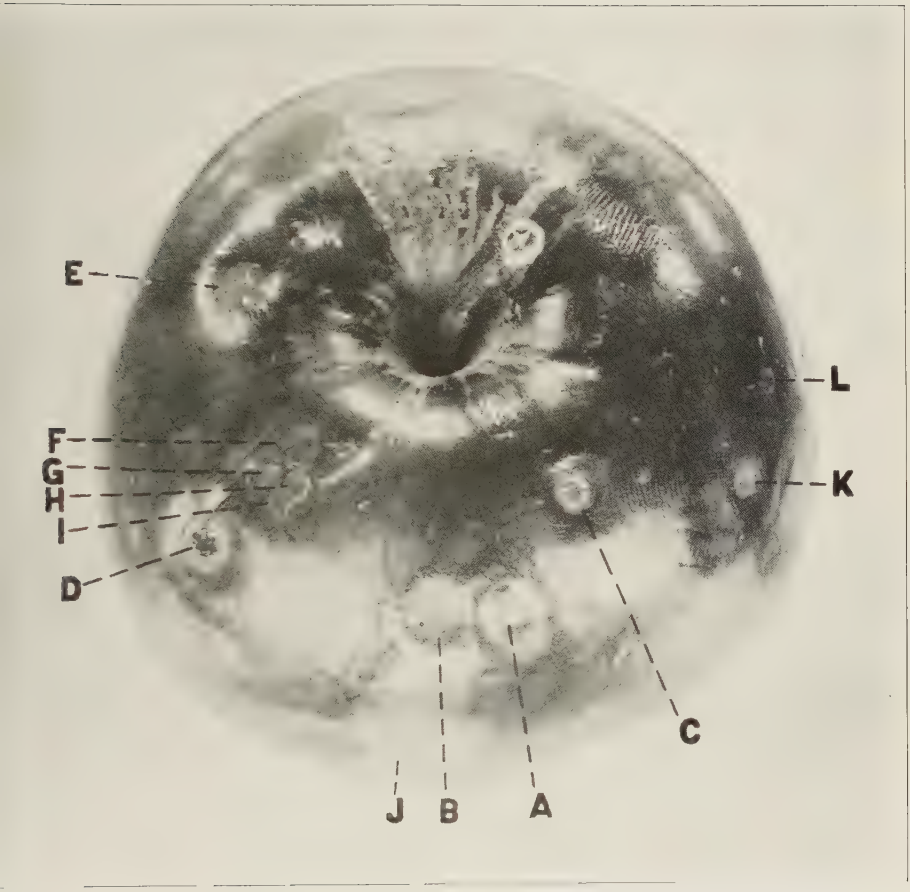

Fig. 20. The apple of Fig. 19 photographed on January 12, 1925. Spots A to E are designated as in Fig. 19. Spots F to L were not detected by ocular examination when the earlier photograph was taken, but were disclosed by the camera, as can be seen by comparison with the faint spots marked equivalently in Fig. 19.

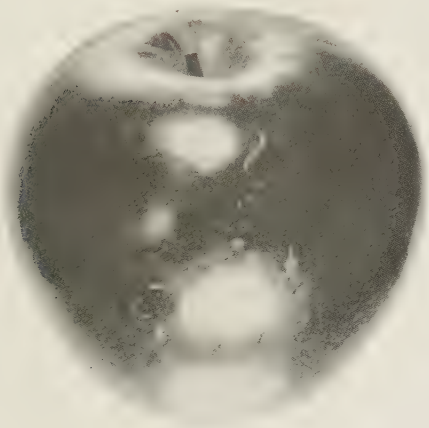

Fig. 21. At top, Ben Davis apple with one small scab spot detected when packed on October 21, 1925. This spot was ringed with ink. The 5 new spots shown in this photograph which was taken three months later on January 21, 1926, developed during storage in a closed barrel in a cool cellar. See Figs. 19 and 20 also for the development of new spots in cold storage. At bottom, spot russeting on Ben Davis apple. (This refers to the small spots of irregular outline, the large light spots being due to reflection of light from the glossy, red skin.)

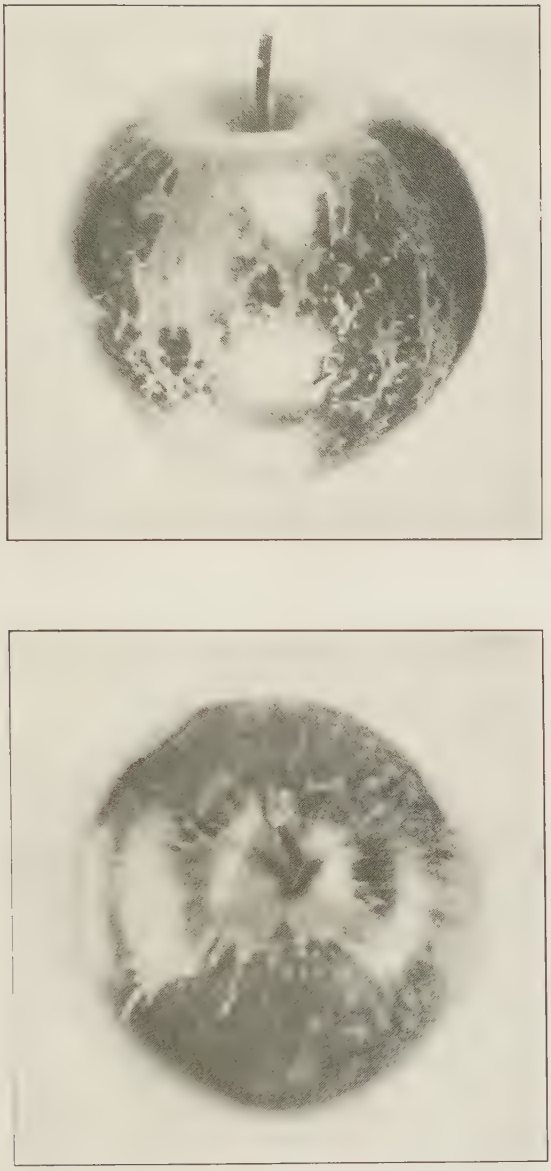

FIG. 22. At top, net russeting on Ben Davis apple, aggregating enough to be noted in the sorting as reducing the grade from A to B. At bottom, solid, even russeting on Ben Davis apple. At the stem end, where it is here, it does not materially injure the appearance of the fruit.

FIG. 23. At top, solid, even russeting on Ben Davis apple. Somewhat rough to the touch, and extensive enough to reduce the grade from A to B when covering a fifth or more of the fruit's surface. At bottom, solid, uneven or bark-like russeting on Ben Davis apple. Reduces the grade from A to B when covering an area as large as a dime, and from grade B to culls when covering over a third of the fruit's surface.

LIST OF RECENT BULLETINS

No. 316. The Importance and Natural Spread of Potato Degeneration Diseases.
No. 317. The Buckthorn Aphid.
No. 318. Interpretation of Dairy Pedigrees.
No. 319. The Blueberry Leaf-beetle and Some of Its Relatives.
No. 320. Influence of Ultra-violet Light on Nutrition in Poultry.
No. 321. Abstracts of Papers not Included in Bulletins, Finances, Meteorology, Index. 1924.
No. 322. Fertilization of Apple Orchards.
No. 323. Potato Aphids.
No. 324. Studies in Milk Secretion. XV. Guernsey sires' progeny performance for milk yield, butter-fat percentage, and butter-fat.
No. 325. Apple Spraying and Dusting Experiments 1918-1924.
No. 326. The Melon Aphid.
No. 327. Studies of Milk Secretion. XVI. Progeny performance of Guernsey sires' sons.
No. 329. Studies in Milk Secretion. XVII. Transmitting qualities of Guernsey sires for milk yield, butter-fat percentage and butter-fat.
No. 330. Varieties of Ensilage Corn for Maine.
No. 331. Potato degeneration diseases: Natural spread and effect upon yield.
No. 332. Sweet-corn Breeding Experiments.

The following bulletins are published in limited editions and are mailed regularly to libraries and to other institutions in exchange. They represent types of publications which are not sent to general mailing lists in the State but will be forwarded to any address on request, as long as the supply lasts.

Bulletin 327

STUDIES OF MILK SECRETION. XVI. PROGENY PERFORMANCE OF GUERNSEY SIRES' SONS. An important guide to success in constructive breeding. The material presented in this bulletin is a study of the average progeny performance for all Guernsey sires' sons where these sons have two or more Advanced Registry daughters. All records are corrected to the mature form production so that the average performance of these sons is directly comparable. The sons are tabulated under their sires and the average progeny performance of the sons of these sires is given for milk yield, butter-fat percentage and butter-fat.

The data are presented to show the variation in the sires' performance and that of his sons. The relation between the son's daughters' milk yields and the sire's daughters' milk yields. Butter-fat percentages and butter-fat are also tabled. The data show that a sire's progeny performance to some extent indicates what his son's probable progeny performance will be.

Bulletin 329

STUDIES IN MILK SECRETION. XVII. TRANSMITTING QUALITIES OF GUERNSEY SIRES FOR MILK YIELD, BUTTER-FAT PERCENTAGE AND BUTTER-FAT. The crux of the dairymen's breeding problem is the selection and maintenance of a bull transmitting high milk yield, butter-fat percentage and butter-fat. To intelligently make such a selection it is necessary to have certain information on the transmitting ability of the bulls within a given breed. Bulletin 329 furnishes this information in a study of the daughter's production in contrast to that of the dam for all Guernsey Advanced Registry sires having two or more daughters. Tables are presented showing the average daughter-dam difference in milk yield, butter-fat percentage and butter-fat for these bulls.